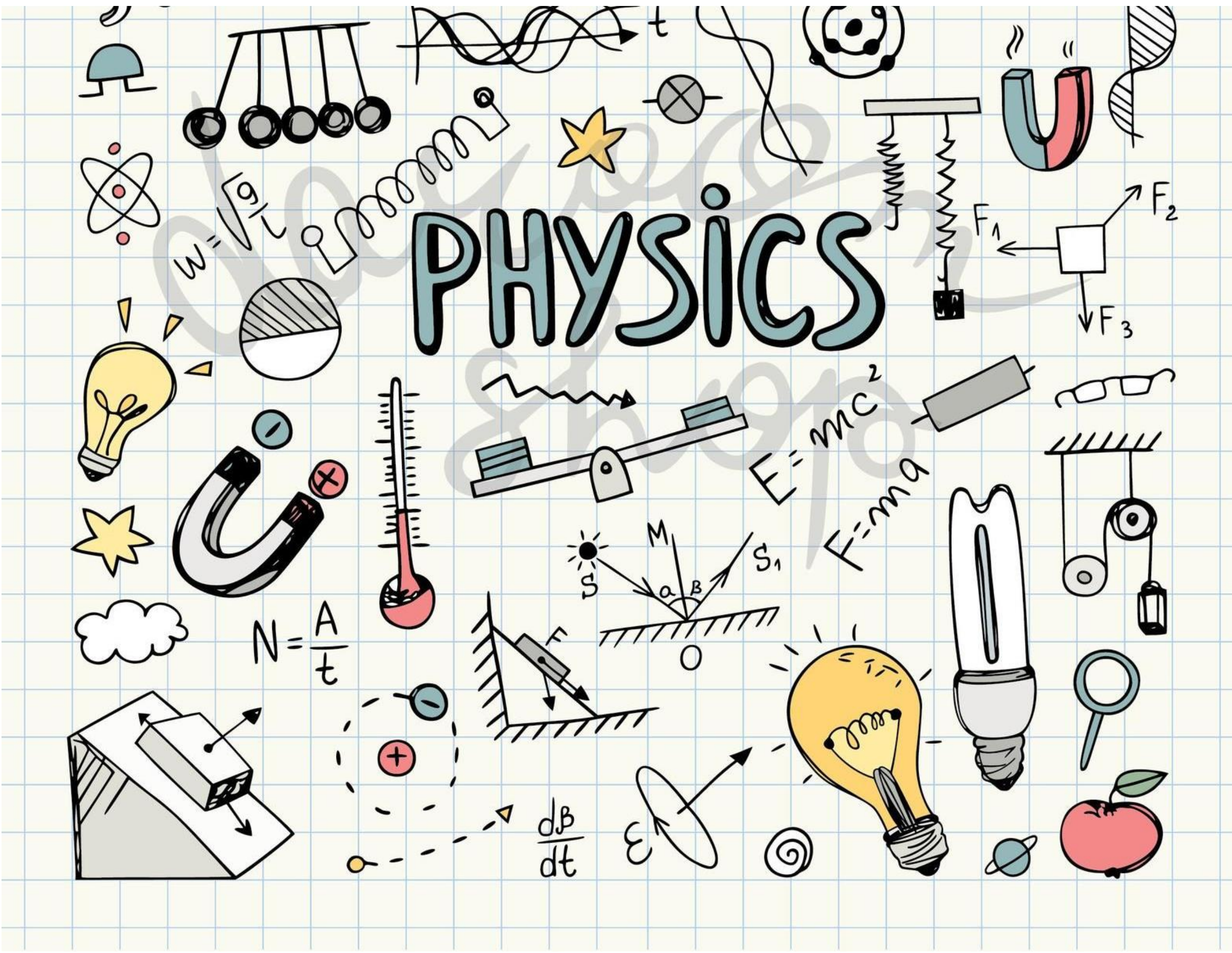
First year Secondary
Second Term



Name: ……………………………………

Class: 10/………………………………

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Important physical and mathematical basics:

1-some unit's conversion:

Factor	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{3}	10^{6}	10^{9}
Prefix	nano	Micro	Milli	Centi	Kilo	Mega	Giga
Symbol	n	µ	m	c	K	M	G

- **Area**

$$cm^2 \xrightarrow{10^{-4}} m^2$$

$$mm^2 \xrightarrow{10^{-6}} m^2$$

- **Volume**

$$cm^3 \xrightarrow{10^{-6}} m^3$$

$$mm^3 \xrightarrow{10^{-9}} m^3$$

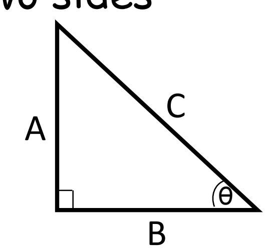
$$cm^3 \xrightarrow{10^{-3}} Liter$$

$$Liter \xrightarrow{10^{-3}} m^3$$

- **Pythagoras theorem**

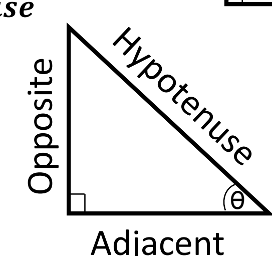
  In the right angle triangle the square of hypotenuse is equal to the sum of squares of the other two sides

  i.e $\boxed{C^2 = A^2 + B^2}$ **so** $\boxed{C = \sqrt{A^2 + B^2}}$



Sin θ = $\frac{Opposite}{Hypotenuse}$, Cos θ = $\frac{Adjacent}{Hypotenuse}$

Tan θ = $\frac{Opposite}{adjacent}$



Unit Two

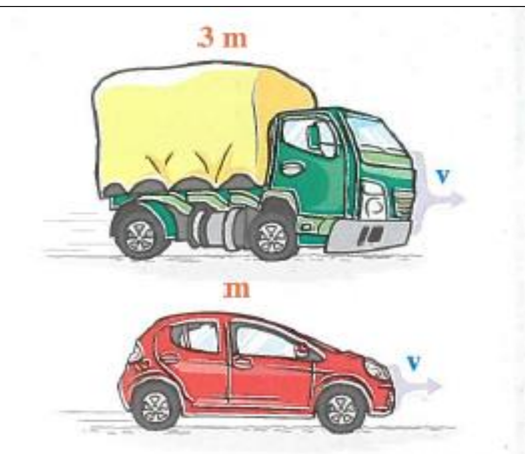
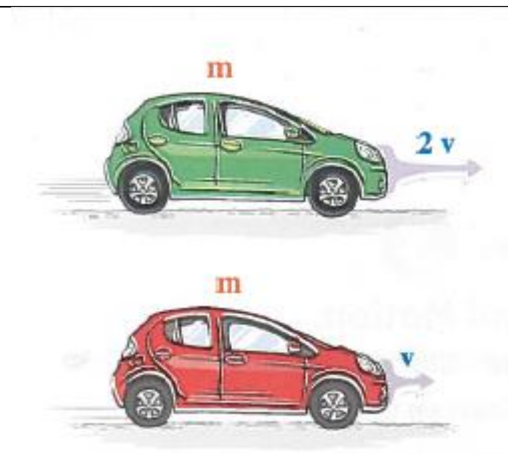
Chapter 3: (*Momentum – Newton's second law*)

We studied Newton's first and third laws in the First Term and now we will study the concept of momentum and Newton's second law

1-Momentum :

$P_L = m * v$

You notice that stopping the objects which are moving under the effect of inertia depends on both:

<table>
<tr><th>Mass</th><th>Velocity</th></tr>
<tr><td>As the mass of the body increases its inertia increases</td><td>As the velocity of the body increases its inertia increases</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>So, it is difficult to stop a truck, while it is easy to stop a car if they have the same velocity.</td><td>So, it is difficult to stop a car that is moving with high velocity, while it is easy to stop it when it is moving with low velocity.</td></tr>
</table>

- Momentum is a vector quantity because its product of scalar quantity (mass) and vector quantity (velocity)

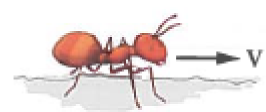
- Momentum's direction is the same direction of velocity

So we concluded that : The velocity (v) and the mass (m) are related to a physical quantity known as momentum (p)Where $\boxed{P_L = m * v}$

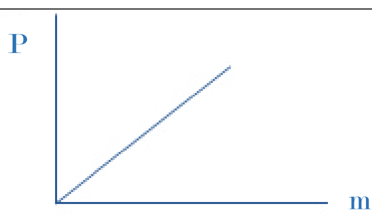
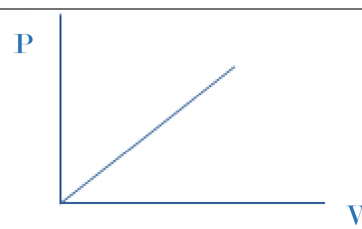
The measuring unit of momentum is : $\boxed{kg.m/s}$ & D.F is $\boxed{MLT^{-1}}$

<u>Notes :</u>

Momentum

For a static body equals zero Even it has a great mass.	For a moving body doesn't equal zero even I has small mass.
	
Because the velocity of the static body equals zero. $P = m * zero = zero$	Because the velocity of the moving body doesn't equal zero, so its momentum doesn't equal zero .

So we can say that :

The momentum is directly proportional to the mass of an object at constant velocity.	The momentum is directly proportional to the velocity of an object at constant mass.
	

Example 1:

Calculate the momentum of a body of mass 5 kg that is moving with a velocity of 2 m/s.

Solution: $m = 5$ kg $v = 2$ m/s $p = ??$

$P = m * v = 5 * 2 = 10\ kg.m.s^{-1}$

Example 2 :

The opposite figure represents a ball of mass 200 g that is placed on a horizontal table. If the ball is pushed to move horizontally towards a vertical wall and collides with it at a velocity of 0.7 m/s then it rebounds with a velocity of 0.4 m/s. Find the change in the momentum of the ball due to the collision neglecting the resistance of air.

Solution: $m = 200$ g $v_1 = 0.7$ m/s $v_2 = 0.4$ m/s

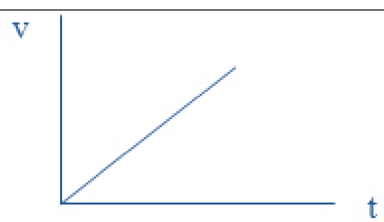
The change in the momentum is given by the relation: $\Delta P = |p_2 - p_1|$

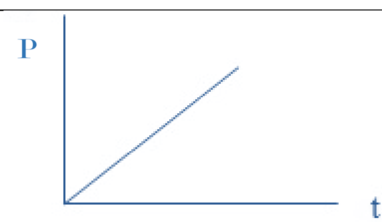
The momentum before collision $P_1 = m * v_1 = 0.2 * 0.7 = 0.14$ Kg.m/s

The momentum after collision $P_2 = m * v_2 = 0.2 * 0.4 = 0.8$ Kg.m/s

$\Delta P = |p_2 - p_1| = |0.8 - 0.14| = 0.22$ Kg.m/s

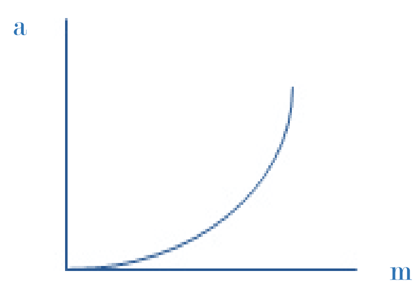
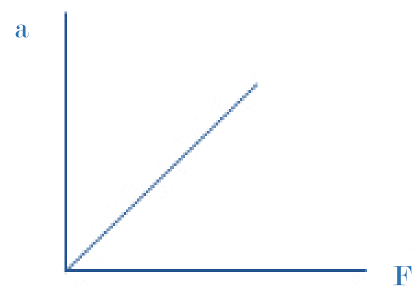
Note: the relation between (Momentum & velocity) directly proportional so the curves of velocity can be the same as the curves of momentum.





2- Newton's second law : $\boxed{\sum F = m.a}$

When a resultant force acts on a car during an interval of time, its velocity increases and acquires an acceleration, so if

Two equal forces is acting on two different masses	Two different forces is acting on two equal masses
	
The higher mass moves with less acceleration	The mass that is affected by a higher force moves with higher acceleration
Acceleration is inversely proportional to mass at constant force. 	Acceleration is directly proportional to force at constant mass. 

The mathematical formula of newton's second law:

$$F = \frac{\Delta p}{\Delta t} = \frac{\Delta(mv)}{\Delta t} = m\,\frac{vf - vi}{\Delta t} = m\,\frac{\Delta v}{\Delta t} = m.a \quad \text{so} \quad \boxed{Ft = mv}$$

So we can say that $\boxed{F = m.a}$ so $\boxed{a = \frac{F}{m}}$

Unit of force is **Newton**

Newton: It is the force that when acts on an object of mass 1 kg accelerates it at 1 m/s in the same direction of the force.

Notes:

If the object was moving in a constant velocity So **∑ F = zero**

If the object was moving in a variable velocity So **∑ F ≠ zero**

If a body moves in a straight line on a horizontal surface under the effect of two forces which are a horizontal pushing force (F_{acting}) and a friction force ($F_{friction}$) between the surface and the moving body, so the resultant force (F_{moving}) that acts on the body is given by the relation :
$F_{moving} = F_{acting} - F_{friction}$

∑ F = F1+F2+F3+F4+ ………… if the forces acting on the body was in the same direction but if one or more forces acting in the opposite direction so we put the force with negative sign ∑ F = F1+F2-F3-F4

If there's a force acting on the body so it is moving with a uniform acceleration in the same direction of acting force.

Example 3 :

A car of mass 1000 kg moved with a uniform acceleration from rest to acquire a velocity of20 m/s after a time period of 5 s. Calculate the pushing force of the car. (assume that there is no frictionforce)

Solution: m= 1000 kg $v_i=0$ $v_f=20$ m/s t=5s F=??

Force = m $\frac{vf - vi}{\Delta t}$

F = 1000 $* \frac{20-0}{5-0}$ = 4000 N

Example 4 :

A force of 20 kg.m/s acts on a body of mass 3 kg that is placed on a horizontal surface to move it at a uniform acceleration of 4 m/s^2. Find the frictional force between the body and the surface.

Solution: m= 3 kg F= 20 N a= 4 m/s^2 $F_{friction}$ =???

$F_{moving} = F_{acting} - F_{friction}$ So $F_{friction} = F_{acting} - F_{moving}$

$F_{friction} = 20 - (3 * 4) = 8$ N

Example 5 :

A force of 1 N acts on a wooden cube to give it a certain acceleration. When the same force acts on another cube, it accelerates it three times the first cube. Find the ratio between the mass of the first cube and the mass of the second cube neglecting the friction forces.

Solution: F= 1 N $a_1 = a$ $a_2 = 3a$

$m= \frac{F}{a}$ $\frac{m1}{m2} = \frac{a2}{a1} = \frac{3a}{a} = 3$

Example 6 : A tennis ball of mass 0.06 kg is projected vertically upwards, then it is hit by a racket when it reaches its maximum height. If it leaves the racket after a time of impact of 4 ms with a velocity of 55 m/s, calculate the average acting force on the tennis ball during the time of impact.

Solution: m= 0.06 kg t = .004 s v_f = 55 m/s F=??

$F = m \frac{vf-vi}{t} =$

……………………………………………………………………………………………………

(solve by yourself)

The difference between Mass & weight :

	Mass (m)	Weight (w)
Definition	The resistance of an object to change its kinematic state.	The force of gravity acting on the body.
Type of physical quantity:	Fundamental scalar quantity	Derived vector quantity, its direction is towards the Earth's center.
Measuring unit :	Kilogram (kg)	Newton (N)
The mathematical relation	m = $\frac{F}{a}$	w= m.g

Example 7

Calculate the weight of a man of mass 70 kg if he was in a car moving horizontally at an acceleration of 4 m/s. (g = 10m/s^2)

Solution: m = 70 kg   a= 4 m/s   g= 10 m/s^2 w=??

W = m.g = 70 * 10 = 700 N

Example 8

A car was pulled by a force of 3000 N to move it at an acceleration of 3 m/s^2. Find the mass and the weight of the car. (given that : g =10 m/s^2)

Solution: F = 3000 N   a= 3 m/s^2 g= 10 m/s^2

m = $\frac{F}{a}$ = $\frac{3000}{3}$ = 1000 kg

w = m.g = 1000 * 10 = 10000 N

Exercise 1

1) Choose the correct answer:

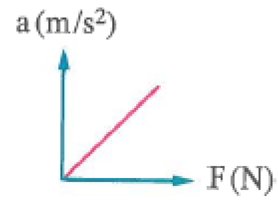
1) When a body falls freely towards the ground its ………………. (Choose two answers)

a. momentum increases b. acceleration remains constant

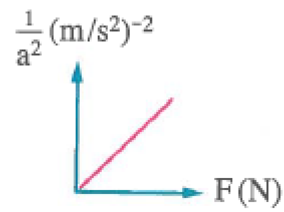
c. weight increases d. mass increases e. velocity decreases

2) The graph that represents Newton's second law is …………………………….

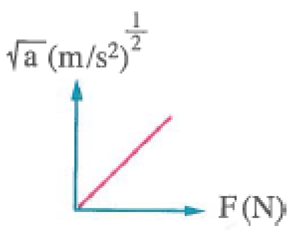
a)



b)



c)



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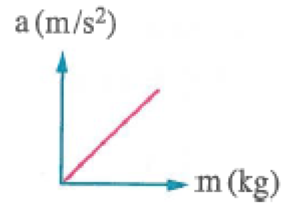


3) If a force of 2 N acts on an object of mass 1 kg, the object acquires ……………..

a. velocity of 2 m/s b. acceleration of 2 m/s^2

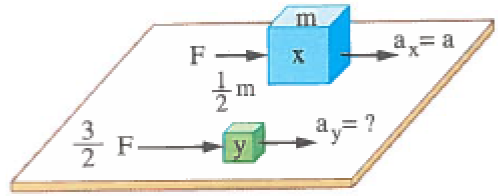
c. acceleration of 1 m/s^2 d. velocity of 1 m/s

4) A rocket goes from rest to 9.6 km/s in 8 minutes. The rocket's mass is 8×10^6 kg.

Assuming a constant acceleration, what is the net force acting on the rocket? ……………

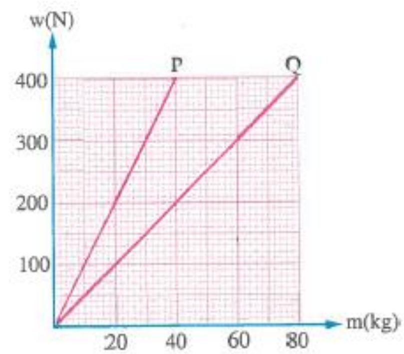
a. 1.6×10^5N b. 9.6×10^5N c. 9.6×10^6N d. 1.6×10^8N

5) The opposite figure represents a body (x) of mass (m) that acts on it a force (F) to accelerate it a uniform acceleration (a) and another body (y) of mass ($\frac{1}{2}$ m) that acts on it a force of ($\frac{3}{2}$ F) to accelerate it a uniform acceleration of ………………..



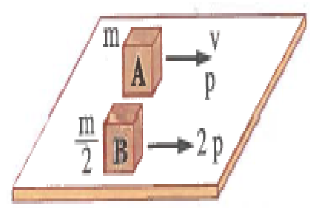
a. $\frac{1}{3}$ a　　b. $\frac{3}{2}$ a　　c. 3 a　　d. 6 a

6) The opposite graph represents the relation between the weight and the mass of a group of bodies when they are placed on two planets P and Q. If a body that weighs 650 N on planet P is translated to planet Q, then ….



	The mass of the body on planet Q (kg)	The weight of the body on planet Q (N)
a.	130	325
b.	130	1300
c.	65	325
d.	65	1300

7) The opposite figure represents a body A of mass m and velocity v and momentum p, and another body B of mass $\frac{m}{2}$ and momentum 2 p so its velocity is ………



a. $\frac{v}{2}$ b. 2 v c. v d. 4 v

8) If the force acting on a body is doubled while its mass is decreased to its half, then the acceleration of its motion …………………

a. decreases to its half b. is doubled

c. increases four times d. decreases to its quarter

9) The ratio between the acceleration of a body of mass 2 kg to that of a body of 4 kg when they move under the effect of the same force is ……………….

a. $\frac{2}{1}$ b. $\frac{1}{2}$ c. $\frac{4}{1}$ d. $\frac{1}{4}$

10) Two forces 3 N and 5 N act on a certain body, which of the following figures represents the least value of the acceleration by which the body will move? …………………………. (Choose two answers)

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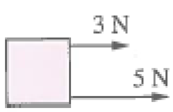
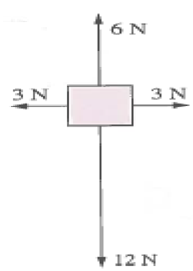
<tr><td>a) 
</td><td colspan="2">b) 
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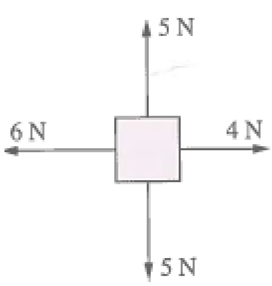
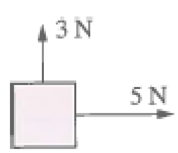
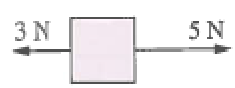
<tr><td>c) 
</td><td>d) 
</td><td>e) 
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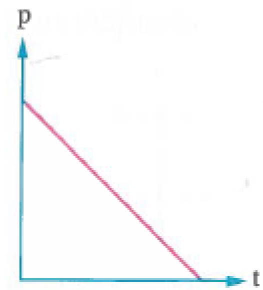
11) The opposite graph represents the relation between the momentum of a body that is affected by a force F and the time, so the force that acts on the body is ……………



a. absent
b. in the same direction of motion
c. in the opposite direction of motion
d. perpendicular to the direction of motion

12) Two static objects of masses 2 kg, 18 kg are affected by two equal forces. They moved in a straight line and covered the same displacement, so the ratio between their final velocities v_1/v_2=

a. $\frac{9}{1}$ b. $\frac{3}{1}$ c. $\frac{1}{3}$ d. $\frac{1}{9}$

13) Rank the following scenarios from the smallest acceleration to the greatest acceleration:

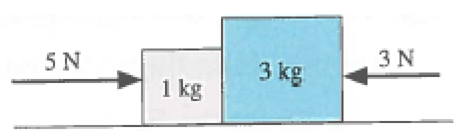
I. Net force F applied to a mass M
II. Net force 2 F applied to a mass M
III. Net force F applied to a mass 2M
IV. Net force 2 F applied to a mass 2M

a. II>I=IV>III b. III>IV=I>II c. I>II>III>IV d. IV>II>III>I

14) 1000 kg car is initially travelling at 30 m/s. The driver applies the brakes suddenly and the friction from the road exerts 9000 N of force on the car. If the car uniformly decelerates to a complete stop, how far does the car travel during the braking process? ....

a. 2 m b. 50 m c. 100 m d. 200 m

15) In the opposite figure: The net force on the bigger mass will be …………



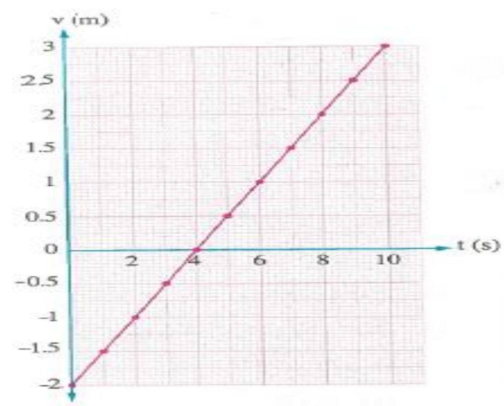
a. greater than 2 N b. equal to 2 N
c. less than 2 N d. no correct answer

16) A vehicle of mass 500 kg and another of mass 1500 kg are moving at the same acceleration. The force acting on the heavier vehicle will be ....the force acting on the less mass vehicle.

a. equal to   b. half   c. twice   b. three times

17) A boy is pushing a 50 kg crate across a frictionless surface. The velocity is changing with time as shown in this graph. What is the magnitude of the force that the boy applies to the crate? ....

a. 5 N
b. 10 N
c. 15 N
d. 25 N



18) The product of the mass of a body and the rate of change of its displacement is called ....

a. force   b. momentum
c. acceleration   d.weight

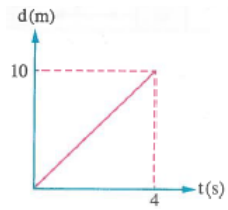
19) The opposite figure shows a ball of mass 0.5 kg that falls freely towards the surface of Earth, so its momentum when it reaches the Earth's surface is ....
(g = 10 m/s^2)

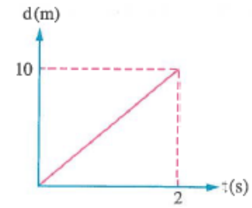
a. 3 kg.m/s   b. 5 kg.m/s   c. 6 kg.m/s   d. 9 kg.m/s

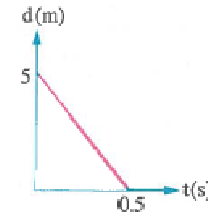
20) The weight of a body is 120 N on Earth, so its weight on the Moon=.........N (notice that: the acceleration due to gravity on the Moon = $\frac{1}{6}$ the acceleration due to gravity on the Earth).

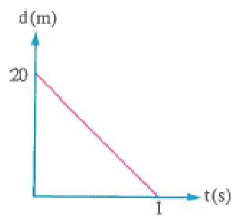
a. 20   b. 60   c. 100   d. 120

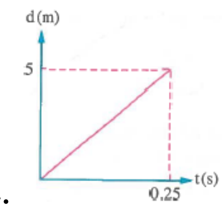
21) The next graphs represent the (displacement - time) curves for five moving bodies that have the same mass, so the two graphs that represents the two bodies of the largest magnitude of momentum are …………… (Choose two answers)

a. 

b. 

c. 

d. 

e. 

22) A jet flies horizontally where its engines produce a total of 20000 N of forward thrust. If the jet's mass is 50000 kg and it accelerates at 0.3 m/s^2, so what is the magnitude of the air resistance against which the jet flies?..................

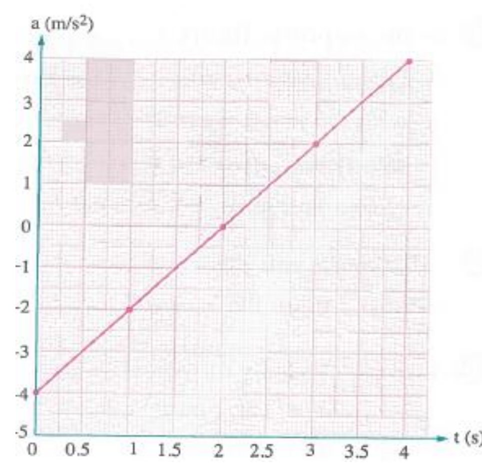
a. 1000 N b. 3000 N

c. 5000 N d. l0000N

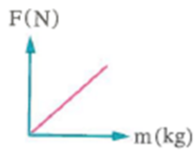
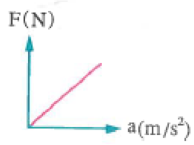
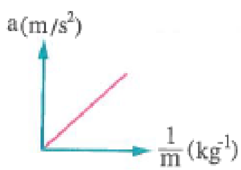
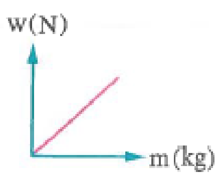
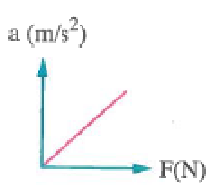
23) The (acceleration - time) graph of an object's motion is shown in this figure. At what time will the forces acting on it become balanced? …………..

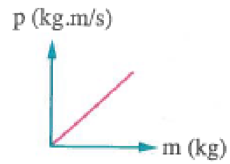
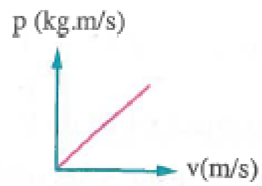
a. 0 b. 1 s

c. 2 s d. 3 s



2) Write down the mathematical relation and mention what the slope equals: Where: (p) is the momentum, (m) is the mass, (v) is the velocity, (F) is the force,(a) is the acceleration and (w) is the weight.

(1) 	…………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………
(2) 	…………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………
(3) 	…………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………
(4) 	…………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………
(5) 	…………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………

(6) 	…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………
(7) 	…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………

<u>3) In the opposite figure:</u>

(a) What happens when both teams pull the rope with the same force?

……
……
………………………

(b) What happens when one team pull the rope with a greater force than the other does?

……
……
………………………

<u>4) Explain</u> Newton's first law.is a special case of Newton's second law.

……
……

<u>5) Would you prefer </u>to have a piece of gold that weighs 1 N on Earth or one that weighs 1 Non the Moon? **<u>Explain.</u>**

(knowing that: Moon's gravity = $\frac{1}{6}$ Earth's gravity).

……
……
……

<u>6) Explain</u> why car companies have recently added airbags to the cars.

……
……
……

<u>7)</u> If a body moves from rest with uniform acceleration (a) to have momentum (p) after time (t), **<u>prove that</u>** its momentum will be (2 p) after time (2 t) from the beginning of its motion.

……
……
……

<u>8)</u> The following figures show three identical cars, each of mass m, **<u>arrange</u>** their maximum accelerations after passing by the traffic light in ascending order assuming that the force of friction is negligible.

……
……
……

9) Problems:

1) Find the force that affects an object of mass 30 kg to:

(a) accelerate it at 3 m/s^2.

……

………

(b) speed it up from rest to 8 m/s during 6 s.

……

………

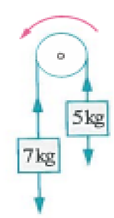
(c) make it move from rest through 50 min 5 s.

……

………

(90 N, 40 N, 120 N)

2) Calculate the acceleration by which the two loads move if the mass of the first load is 5 kg and the second load is 7 kg by neglecting the air resistance. ($g = 10\ m/s^2$)



……

…………………………………………………………………………………………………… *(1.67 m/s^2)*

3) A body of mass (m) is affected by a number of different forces according to the following table:

F (N)	10	20	30	40	50
A (m/s^2)	1	2	3	4	5

(a) Represent these data graphically where force is on the ordinate while acceleration is on the abscissa.

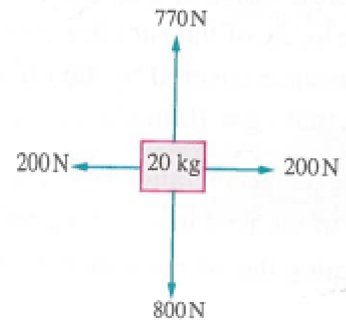
(b) From the graph find the value of the line slope and mention what it represents.

……

……

……………………………………………………………………………………… *(m = 10 kg)*

4) Calculate the resultant force and the acceleration of each mass in the following figures:

(a)	(b)
	
…………………………………………………… …………………………………………………… ……………………………………………………	…………………………………………………………… …………………………………………………………… …………………………………………………

(250 N, 5m/s², 30 N, 1.5 m/s²)

5) When a body of mass 8 kg went through a rough plane its velocity decreased due to the friction till it has stopped after a distance of 40 m. Calculate the friction force.

………

………

……………………………………………………………………………………………………*(-40 N)*

6) A car of mass 725 kg was travelling by a velocity of 72 km/h when the driver applied the brakes for 2 s the car was affected by an average force of 5×10^3 N. Calculate:

(a) The change in the momentum of the car during this period.

………

………

……

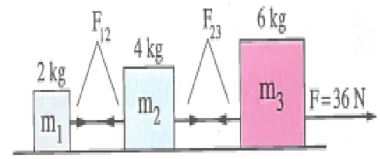
(b) The velocity of the car at the moment of releasing the brakes.

………

………

…………………………………………………………………………………*(-10^4 kg.m/s, 6.2 m/s)*

7) Three masses are connected together by weightless threads as shown in figure where they are pulled on a smooth surface by a horizontal constant force to move them by a uniform acceleration. Find:



(a) The common acceleration of these masses.

……

……

……

(b) The tension force in each thread.

……

……

……

(3 m/s², 6 N, 18 N)

8) A car was moving at velocity 20 m/s in a straight road. The driver applied the brakes to decelerate the car at 5 m/s². Find:

(a) The time taken to stop the car and the distance required.

……

……

……

(b) The type of the force that slowed down the car and the direction of its action.

……

……

……

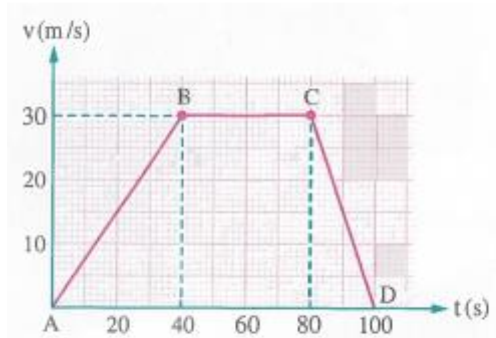
(c) The magnitude of the force that stopped the car if the car has a mass of 600 kg.

……

……

(4 s, 40 m, negative and opposite to the direction motion, - 3000 N)

9) An object of mass 80 kg is moving during 100 s according to the opposite graphical relationship:



(a) Find the greatest velocity reached by the object.

………

………

………

(b) What is the type of the object motion in the stage AB and the stage BC?

………

………

(c) Calculate the force acting on the object in each stage.

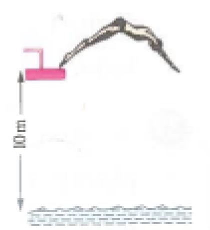
………

………

(30 m/s, uniform acceleration, uniform velocity, 60 N, 0, -120 N)

10) A diver of mass 50 kg jumps from 10 m high diving board. Find:

(a) The diver velocity at hitting the water surface.



………

………

(b) The water resistance to the motion of the diver if his motion ends at 2.45 m deep in water. ($g = 9.8\ m/s^2$).

………

…………………………………………………………………………………… *(14 m/s, -2000 N)*

11) A body at rest is affected by a force equals half its weight. Find:
(a) Its velocity after 2 s.

……
……
………

(b) The distance covered by it during 2 s.
(Assuming that: the acceleration due to Earth's gravity= 10 m/s^2)

……
……
………

(10 m/s, 10 m)

12) A ball of mass 0.5 kg is left to fall freely from a height of 20 m. Calculate its momentum just before it touches the ground neglecting the resistance of air.

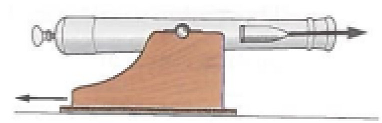
……
……
………

(10 kg.m/s)

13) Two equal forces act on two bodies. The first body has acquired acceleration of 8 m/s^2 while the velocity of the second body is changed from rest to 48 m/s during 3 s. If the mass of the first body is 5 kg, what is the mass of the second body?

……
……
…………………………………………………………………………………………… *(2 .5 kg)*

14) A missile of mass 3.2 kg is projected from a cannon that is placed horizontally as in the opposite figure. The missile moves with acceleration of 2500 m/s^2 and the cannon recoils with acceleration of 0.76 m/s^2. If the cannon is placed on a frictionless surface, calculate the mass of the cannon.



………

……………………………………………………………………………………… *(1.05×10^4 kg)*

15) A ball fell freely from a tower onto a sandy soil. Its velocity when reaching the ground is 90 m/s. Calculate:

(a) The tower height.

………

………

(b) The ball's mass if it sank into sand and stopped 1 s later.

(giving that: the sand resistance to the ball motion is 3000 N , free fall acceleration= 10 m/s^2)

………

……………………………………………………………………………………… *(405 m, 33.3 kg)*

16) If a car of mass 800 kg decelerates by 6 m/s2 when applying the brakes.

(a) Calculate the acting force on the car when the brakes are applied.

………

……

(b) If a trailer of mass 400 kg is towed by the car, calculate the deceleration of the car when applying the brakes.

....

....

....*(- 4800 N, -4 mil)*

17) An elephant pulls a log of mass 0.5 ton by a rope with uniform velocity along the ground where the rope makes an angle 60° to the horizontal as shown in the figure. Given that the frictional force between the log and the ground is 200 N, find:

(a) The tension force in the rope.

....

....

....

(b) The tension force in the rope required to make the log move at acceleration 2 m/s^2.

....

....

....

(400 N, 2400 N)

18) An eagle of mass 10 kg flies at 20 m/s and a gazelle of mass 50 kg is running at 5 m/s. Which of them has greater momentum?

....

....

(The momentum of the gazelle > That of the eagle)

19) A car of mass 1000 kg was moving in a velocity of 20 m/s. The driver applied the brakes, so it stopped after 10 seconds. Find:

(a) The momentum of the car before using the brakes.

....

....

(b) The momentum of the car after 10 seconds.

……

……

(c) The average force of the brakes acting on the car.

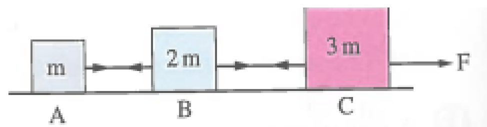
……

……

…………………………………………………………………………………… *(2×10^4 kg.m/s, 0, - 2000 N)*

20) A group of three masses as shown in figure moves at a changeable velocity by the effect of a resultant force F = 30 N. Find:

(a) The tension force in the thread between (A) and (B).



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(b)The tension force in the thread between (B) and (C).

……

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………………………………………………………………………………………… *(5 N, 15 N)*

Unit Three

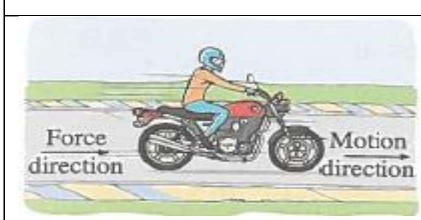
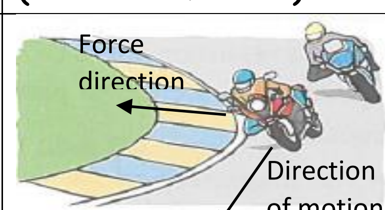
Chapter 1: (*laws of circular motion*)

Circular motion is very common in the universe such as:

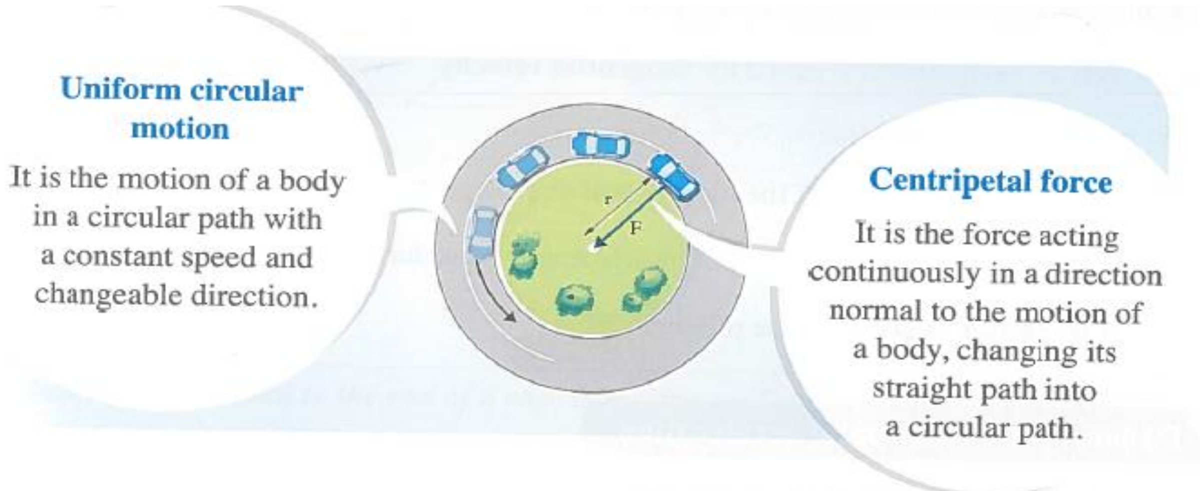
- **Motion of planets around a star.**
- **Motion of moons around a planet.**

Through the study of Newton's second law you have learned that:

When a net force acts on a moving body its velocity changes which means that it acquires acceleration.
And the change in velocity depends on the direction of the acting net force relative to the direction of motion so we have 3 cases:

In the same direction of motion	In the opposite direction of motion	Perpendicular to the direction of motion
The speed of the moving object increases	The speed of the moving object decreases	The speed of the moving object remains the same
The direction of motion does not change.	The direction of motion does not change.	The direction of motion changes. (circular motion)
 When motorcyclist pumps more fuel	 When motorcyclist applies the brakes	 When motorcyclist leans his body to left or right

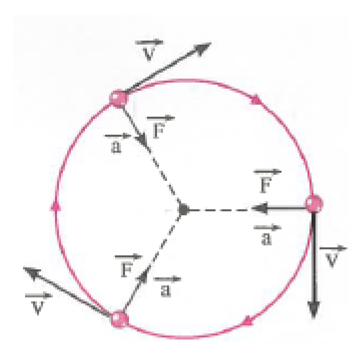
As you see for an object to move in a uniform circular motion, it must be affected by a constant resultant force that is perpendicular to its path towards the circle's center which is called the centripetal force.



<u>Laws of circular motion:</u>

1- Centripetal acceleration 2- Centripetal force

<u>**First** Centripetal acceleration:</u>

When a resultant force (F) acts on a body of mass (m) that moves at speed (v) in a circular path of radius (r) normally to the direction of motion: • **The magnitude of the velocity (v) remains constant along its path.** • **The direction of the velocity changes from one point to another on its path.**	

The change in the direction of velocity leads to the existence of an acceleration called the centripetal acceleration (a)

<u>**Centripetal acceleration:**</u> It is the acceleration acquired by an object moving in a circular path due to the change in the direction of its velocity.

If the body completes one circular revolution in an interval of time (T) which is called the periodic time, the velocity (v) by which the body moves is called the tangential velocity and it is given by relation.

$$\boxed{V = \frac{2.\pi.r}{T}}$$

And its direction is always in the direction of the tangent to the circular path.

Periodic time: It is the time taken by a body to make one complete revolution.

- If the body completes number (N) of complete revolutions during time (t), then the periodic time of its motion is given by the relation. $\boxed{T = \frac{t}{N}}$
- Rule of centripetal acceleration is $\boxed{a_c = \frac{v^2}{r}}$ ………………………VIP

Where (v) is velocity of the object and (r) is the radius of the circle path.

- Centripetal acceleration is directly proportional to the square of the tangential velocity at a constant radius of the circular path & Slope between v^2 (on x-axis) & centripetal acceleration (y-axis) is $(\frac{1}{r})$
- Centripetal acceleration 'a_c' is inversely proportional to the square of the radius of the circular path at a constant tangential velocity.

Slope between $\frac{1}{r}$ (on x-axis) & centripetal acceleration 'a_c' (y-axis) is (v^2).

Example 1:

A ball that is attached to the end of a rope is moving uniformly in a horizontal circular path of radius 0.6 m. If the ball completes two revolutions in one second, calculate the tangential velocity of the ball and also its centripetal acceleration.

Solution: r= 0.6 m T = 0.5 s

V = $\frac{2\,\pi\, r}{T}$ = $\frac{2\,\pi\,(0.6)}{0.5}$ = 7.5 m/s So a = $\frac{v^2}{r}$ = $\frac{(7.5)^2}{0.6}$ = 94.7 m/s^2

Example 2:

A body moves in a circular path with a tangential velocity of 10 m/s.

Calculate its average velocity during one quarter of a revolution.

Solution: v= 10 m/s d= $r\sqrt{2}$ t= $\frac{1}{4}$T v_{avg}=??

V = $\frac{2\,\pi\, r}{T}$ so 10 = $\frac{2\,\pi\, r}{T}$ then we can say $\frac{10}{2\,\pi}$ = $\frac{r}{T}$ …………(1)

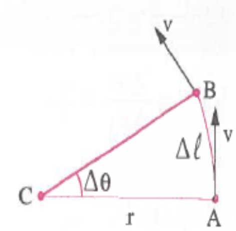
v_{avg} = $\frac{d}{t}$ = $\frac{r\sqrt{2}}{0.25T}$ but $\frac{r}{T}$ = $\frac{10}{2\,\pi}$ so v_{avg} = $\frac{10\,\sqrt{2}}{0.25*2\,\pi}$ = 9 m/s

Enrichment information

Calculating the angular velocity :

If a body moves at a tangential velocity (v) along a circle of radius (r) from point (A) to point (B), covering a distance ($\Delta \ell$) corresponding to an angle ($\Delta\theta$), during time interval (Δt).

Then the value ($\frac{\Delta\theta}{\Delta t}$) is known as the **angular velocity (ω)**.



$$\boxed{\text{Angular velocity } (\omega) = \frac{2\,\pi}{T}}$$

Second Centripetal force:

When a centripetal force acts on a body of mass (m) to move it in a circular path with a centripetal acceleration (a), so according to Newton's second law the force is given by the relation : F= ma

$a_c = \frac{v^2}{r}$ so $\boxed{F_c = m\,\frac{v^2}{r}}$

The factors that affect centripetal force:

- The object's mass (m): centripetal force is directly proportional to the object's mass.
- The tangential velocity (v): centripetal force is directly proportional to the tangential velocity.
- The radius of the circular path (r):): centripetal force is inversely proportional to the radius of the circular path.

Notes:

Laws can be used to determine the centripetal force:

1- By knowing the centripetal acceleration: $\boxed{F_c = ma_c}$

2- By knowing the periodic time : $\boxed{F_c = m\,\frac{4\pi^2 r}{T^2}}$

3- By knowing the tangential velocity: $\boxed{F_c = m\,\frac{v^2}{r}}$

4- By knowing the frequency: $\boxed{F_c = m * 4\pi^2 * r * f^2}$ where $f = \frac{1}{T}$

Example 3: A stone of mass 600 g is attached to a string of length 10 cm and rotated at a speed of3 m/s. Find the centripetal force. And what do you expect to happen if the greatest tension force in the string just before cutting is 50 N?

Solution: m= 0.6 kg r=0.1 m v= 3 m/s F_c= ??

$F_c = m\,\frac{v^2}{r} = 0.6 * \frac{3^2}{0.1} = 54$ N

Example 4: A body of mass 0.5 kg moves along the circumference of a circle of radius 2m at a constant linear velocity of 10 m/s. Find: (a) The linear and centripetal acceleration.

(b) The centripetal force that acts on the body.

Solution: m= 0.5 kg r= 2 m v= 10 m/s

$a_c = \frac{v^2}{r} = \frac{100}{2} = 50\ m/s^2$

$F_c = m\,\frac{v^2}{r} = 0.5 * 50 = 25$ N

Example 5 :

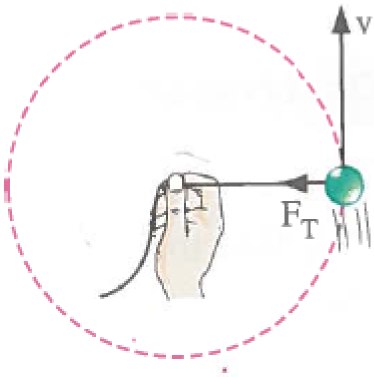
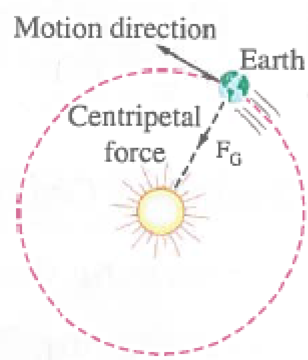
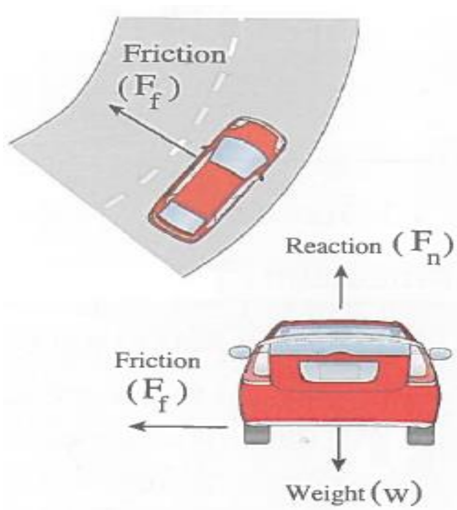
If a rubber stopper of mass 13 g whirled horizontal circular path of radius 0.93 m to make 50 revolutions in a time of 59 s. Find the mass of the load which is attached to the other end of the string.(knowing that: g = 10 m/s, π= 3.14)

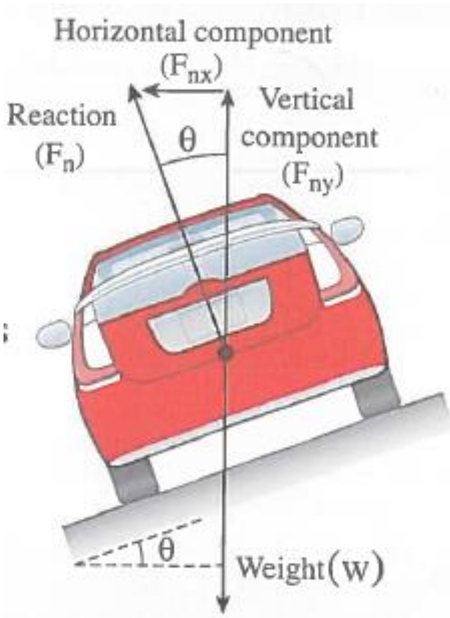
Solution: m= 0.013 kg r= 0.93 m N= 50 t = 59 s

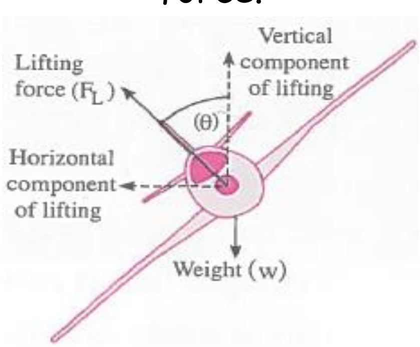
$T = \frac{t}{N} = \frac{59}{50} = 1.18$ s (v) $= \frac{2\pi r}{T} = \frac{2\pi(0.93)}{1.18} = 4.95$ m/s

$Fc = m\,\frac{v^2}{r} = 0.013 * \frac{(4.95)^2}{0.93} = 0.34$ N $m_{load} = \frac{F}{g} = \frac{0.43}{10} = 0.034$ kg

Types of centripetal force:

<table>
<tr>
<td>1- Tension force (F_t)

</td>
<td>When pulling a body by a string or a wire, a tension force is originated.
• If this tension force is normal to the direction of motion of the moving body at constant velocity, this force causes the body to move in a circular path.
Which means that the tension force in the string acts as a centripetal force.</td>
</tr>
<tr>
<td>2- Gravitational force (F_g)

</td>
<td>The force of attraction between the Sun and the Earth is acting in a direction perpendicular to the path of the Earth. This force causes the Earth to move in a circular path around the Sun.
Which means that the gravitational force in this case acts as a centripetal force.</td>
</tr>
<tr>
<td>3- Friction force(F_f)

</td>
<td>When a car turns in a circular path or a curve, a frictional force between the road and the car tires is originated
This force acts normally to the direction of the car's motion towards the center of the circle causing the car to move in a curved path.
Which means that the frictional force acts as a centripetal force.</td>
</tr>
</table>

4- The sum of the horizontal components of each of the reaction force and the friction force towards the center of rotation.  	When a car moves in a banked circular path (inclined to the horizontal at an angle θ) it is affected by more than one force, such as : -The reaction force: that always acts normally to the car and by resolving this reaction into two components, the horizontal component acts towards the center of the circle and helps the car to move in a curved path. - The frictional force: its horizontal component also acts towards the center of the circle and helps the car to move in a curved path. Which means that the centripetal force is the sum of the horizontal components for each of the reaction force and the frictional force which act in a direction towards the center of rotation

5-The horizontal component of the lift force.  	• The lifting force acts normally to the aero plane body. • When the aero plane tilts, the horizontal component of the lifting force acts normally to the direction of motion and towards the center of rotation causing the plane to move in a circular path. So the horizontal component of the lifting force acts centripetal force.

Exercise 2

1) Choose the correct answer:

1) The centripetal force acting on a car that moves in a circular path that inclines at an angle with the horizontal is resulted from …….

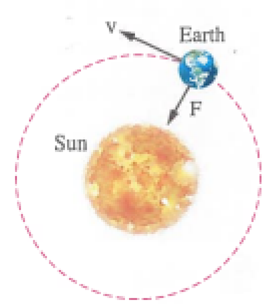
a. the sum of the vertical components for each of the friction force and the reaction force.

b. the sum of the horizontal components for each of the friction force and the reaction force.

c. the sum of the vertical component of the friction force and the horizontal component of the reaction force.

d. the sum of the horizontal component of the friction force and the vertical component of the reaction force.

2) The opposite figure represents the motion of the Earth around the Sun in a circular path where the direction of the centripetal acceleration is …………………
(Choose two answers)



a. in the same direction of the force F.

b. perpendicular to the direction of the force F.

c. in the same direction of the tangential velocity of the Earth(v).

d. in the opposite direction of the tangential velocity of the Earth (v).

e. perpendicular to the direction of the tangential velocity of the Earth (v).

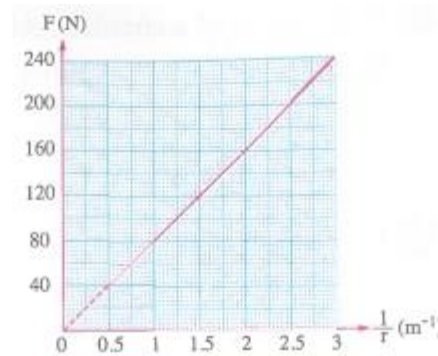
3) If an object moves in a circular path, then all the following statements are correct except …….

a. the centripetal force changes the direction of motion.

b. the centripetal force increases the velocity of the object

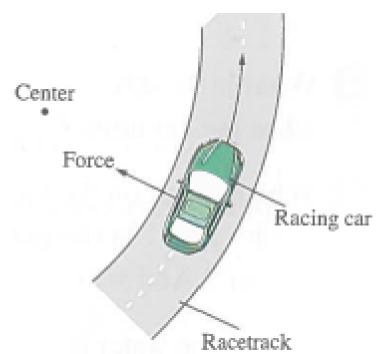
c. the acceleration = $\frac{v^2}{r}$ d. the velocity = $\sqrt{ar}$

4) The opposite graph represents the relation between the centripetal force (F) that acts on a body of mass 5 kg moving in a uniform circular path with tangential velocity v and the reciprocal of the radius of this path ($\frac{1}{r}$),so……………….(Choose two answers)



a. the tangential velocity of the body equals 2 m/s
b. the tangential velocity of the body equals 4 m/s
c. the momentum of the body equals 20 kg.m/s
d. the momentum of the body equals 80 kg.m/s

5) A racing car moves round a circular part of a racetrack.
(i)The force that acts toward the center of the circular part of the racetrack is caused by……



a. air resistance b. gravity
c. friction d. lifting

(ii) The force is called …………….
a. centripetal force b. perpendicular force
c. circular force d. gravitational force

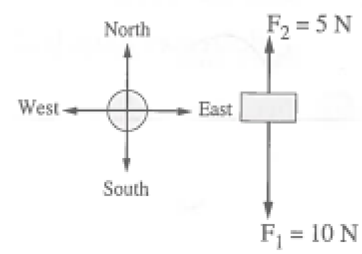
(iii) If another racing car has a greater mass and travels at the same speed around the same racetrack, then the force will need to …………….
a. decrease b. stay the same
c. increase d. vanish

(iv) When the racing car goes faster, the force will need to ……………

a. decrease b. stay the same

c. increase d. vanish

6) A body moves towards east on a plane frictionless surface with constant velocity. If two forces F_1 and F_2 act on it as in the opposite figure, then its velocity will change in ………….



a. magnitude only b. direction only

b. magnitude and direction d. no correct answer

7) A car moves around a curve of radius 100 m with constant speed 20 $m.s^{-1}$. So, its centripetal acceleration equals……….. $m.s^{-2}$.

a. 4 b. 2 c. 5 d. 2.5

8) A planet of mass 10^{20} kg rotates in a circular path such that its displacement within quarter cycle is $\sqrt{2 x 10^{10}}$ m and covers half a cycle within 10^6 s. Then the centripetal force acting on the planet is …..

a. $2\pi \times 10^{10}$ N b. $\pi \times 10^{20}$ N

c. $\pi^2 \times 10^{18}$ N d. $\sqrt{\pi} \times 10^{30}$ N

9) In the display window of a toy store at the mall, a battery-powered plane is suspended from a string and flying in a horizontal circle. The 631 gram plane makes a complete circle every 2.15 seconds. The radius of the circle is 0.95 m. Determine the centripetal force acting upon the plane?

a. 5.13 N b. 3.45 N c. 5.7 N d. 10.3 N

10) The Moon takes 27.3 days to orbit the Earth at an average radial distance of 385000 km from the center of the Earth. What is the acceleration of the Moon?

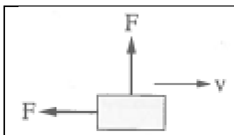
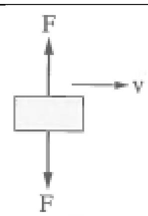
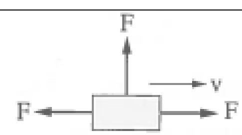
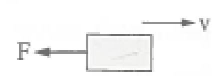
a. 2.73×10^{-3} m/s^2 b. 4.96×10^{-3} m/s^2

c. 9.8×10^{0} m/s^2 d. 1.94×10^{-3} m/s^2

11) A man of mass 50 kg rides a bicycle on a curved road of radius 30 m with a speed of 2 m/s. If the centripetal force that acts on both the man and the bicycle is 10 N, so the mass of the bicycle is

a. 25 kg b. 50 kg c. 75 kg d. 100 kg

12) The next figures represent the effect of some forces on a body that moves with velocity v, so which of them can rotate in a uniform circular path?

 a)	 b)	 c)	 d)

13) When a body moves in a uniform circular motion along the circumference of a circle of radius (r), so……………………

(Choose two answers)

a. the centripetal force acts on changing the velocity direction

b. the body moves with constant speed

c. the magnitude of the body's velocity = Centripetal acceleration x r

d. the body's centripetal acceleration is in the same direction of motion

e. the direction of the linear velocity is towards the center of the circular path

14) The ratio between the centripetal forces acting on two bodies of equal masses when the first body moves with a speed of 5 m/s in a circle of diameter 4 m and the second body moves with a speed of 10 m/s in a circle of diameter 8 m is……….

a. $\frac{2}{3}$ b. $\frac{1}{4}$ c. $\frac{1}{3}$ d. $\frac{1}{2}$

15) In one of the amusement park games, the chairs rotate in a uniform circular path.

If one of the chairs is 1.5 m away from the center and another chair is 2 m away from the center and both of them are on the same straight line away from the center, so which of them has the largest tangential velocity?

a. The chair that is 1.5 m away from the center

b. The chair that is 2 m away from the center

c. Both of them have the same velocity

d. The periodic time must be given to determine the answer

Second: Essay questions

1) Explain the following statements:

(1) Although a body moving in a uniform circular motion and acquires acceleration, its linear speed is constant.

………

………

………

(2) The Earth rotates around the Sun in the same orbit.

………

………

………

(3) When a car moves in a curved road, it maintains its curved path and does not skid.• The car does not slip on moving in a curved path.

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………

(4) The car that moves in a curved path that inclines on the horizontal with an angle doesn't skid.

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………

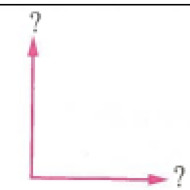
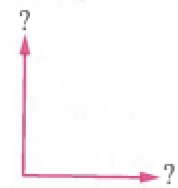
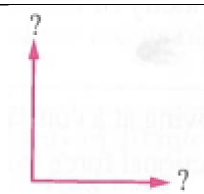
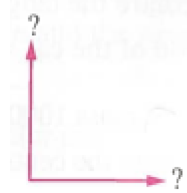
(5) On designing the curved paths in roads and railways we must take into account the centripetal force.

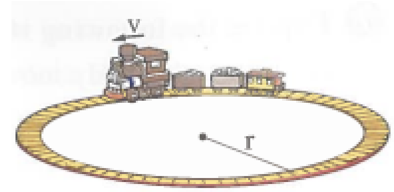
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………

(6) It is recommended to prevent driving heavy trucks on dangerous curved roads.

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
………………………………

2) You have four graphs under each of them a statement, draw these graphs and write down the physical quantities which are represented on the axes:

a. The slope gives the centripetal force	 (1)
b. The slope equal $\frac{v^2}{r}$	 (2)
c. The slope equals $\frac{m}{r}$	 (3)
d. The slope equals mv^2	 (4)

3) The figure shows a train that moves in a circular path of radius 1 m. If the train makes a complete revolution in 12 s, complete	

(a) The path of one revolution is determined from the relation: *l* = ……. m

(b) The velocity can be determined from the relation: v = …… m/s

(c) The centripetal acceleration is determined from the relation:
a = ….. m/s

<u>4) </u>A car starts its motion in a curved slippery road, where the driver notices that the car skids out of the curved road. **<u>Explain.</u>**

………
………
………
………………………………

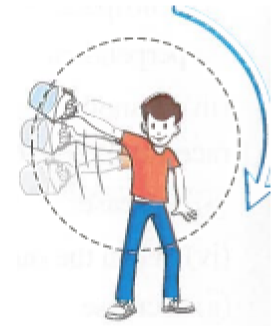
<u>5) </u>The driving instructor assured that the trainees should decrease the velocity of the car before entering a curved road to maintain the safety of the car and the safety of the driver. From your study of the circular motion, **<u>what is the reason of this?</u>**

………
………
………
………………………………

<u>6) </u>On rotating a stone attached to the end of a string in a circular path. **<u>What</u>** is the direction of the force acting on the stone? **<u>What</u>** at is its effect? **<u>What</u>** is the direction of motion if the string is cut?

………
………
………
………………………………

7) **Would** the water be kept inside the bucket when you rotate it in a vertical plane as shown in the figure? **Explain your answer.**

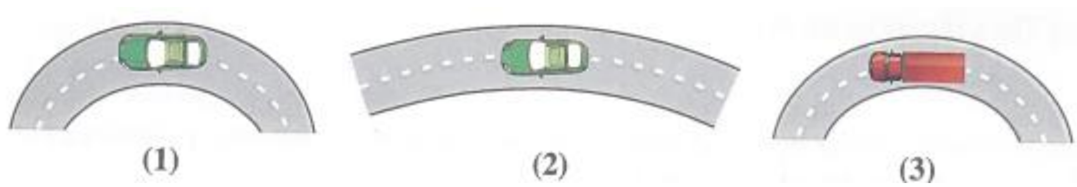


……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

8) The next figures shows three cars (1) , (2) and (3) that move in three curved road with the same velocity. If the mass of each of car (1) and car (2) is m and the mass of car (3) is 3 m and the roads of the two cars (1) and (3) have the same radius which is double the radius of the road of car (2), **arrange** the cars in descending order according to the possibility of slipping. **Explain your answer.**



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Third: Problems

(1) Centripetal force of 1800 N acts on a body of mass 10 kg to move it in a circular path of radius 5 m, find:

a) The velocity of the body.

……………………………………………………………………………………………………

b) The centripetal acceleration.

……………………………………………………………………………………………………

……………………………………………………………………………*(30 m/s, 180 m/s^2)*

2) A body of mass 100 g moves along the circumference of a circle of radius 50 cm at a uniform circular motion. If it takes a time of 90 s to make 45 complete revolutions, calculate

a) Its periodic time.

....

c) Its centripetal acceleration.

....

b) Its linear velocity.

....

(2 s, 1.57 m/s, 4.9 m/s)

3) An object of weight 100 N moves with a velocity of 10 m/s in a circular path of radius 10 m, if the acceleration due to gravity is 10 m/s^2, find:

(a) The centripetal acceleration.

....

(b) The required time for two revolutions.

....

(c) The displacement in half a revolution.

....

(d) The centripetal force.

....

(10 m/s, 12.6 s, 20 m, 100 N)*

4) Mariam tied a ball of mass 0.2 kg to the end of a rope of length 1 m. She makes the ball move in a circle by holding the other end with a suitable movement from her hand with linear velocity of 8 m/s. If the rope withstands a tension force of 15 N, will the rope be cut? And why?

....

....*(The rope will not be cut)*

5) A helicopter toy of mass 100 g flies in a circular path of radius 1 m and rotates at a rate of 100 revolutions in 20 s. Calculate:

(a) The linear tangential velocity of the toy.

………

……….

(b) The centripetal acceleration.

………

………

(c) The centripetal force.

………

……………………………………………*(31.4 m/s, 985.96 m/s^2, 98.596 N)*

6) A racing car of mass 905 kg moves in a circular path of circumference 3.25 km.

Calculate the tangential velocity of the car if the force required to keep the circular motion of the car = 2140 = N.

………

……

…………………………………………………………………………………………*(34.98 m/s)*

7) An object of mass 5 kg moves in a circle of radius 2 m at a uniform speed of 5 m/s. Find each of:

(a) The centripetal acceleration.

(b) The linear acceleration

(c) The centripetal force.

………

………

………

……………………………………………………………………………*(12.5 m/s^2, 62.5 N, 0)*

Unit Three

Chapter 2

Lesson 1: (*Universal law of gravitation*)

<table>
<tr><td>The Moon rotates around the Earth</td><td></td><td rowspan="3">All the celestial bodies move in circular motion or roughly circular motion.</td></tr>
<tr><td>The planets rotate around sun</td><td></td></tr>
<tr><td>The sun rotates around the center of the galaxy</td><td></td></tr>
</table>

Isaac Newton had concluded some basic assumptions that helped him to formulate the general gravitational law, of these assumptions:

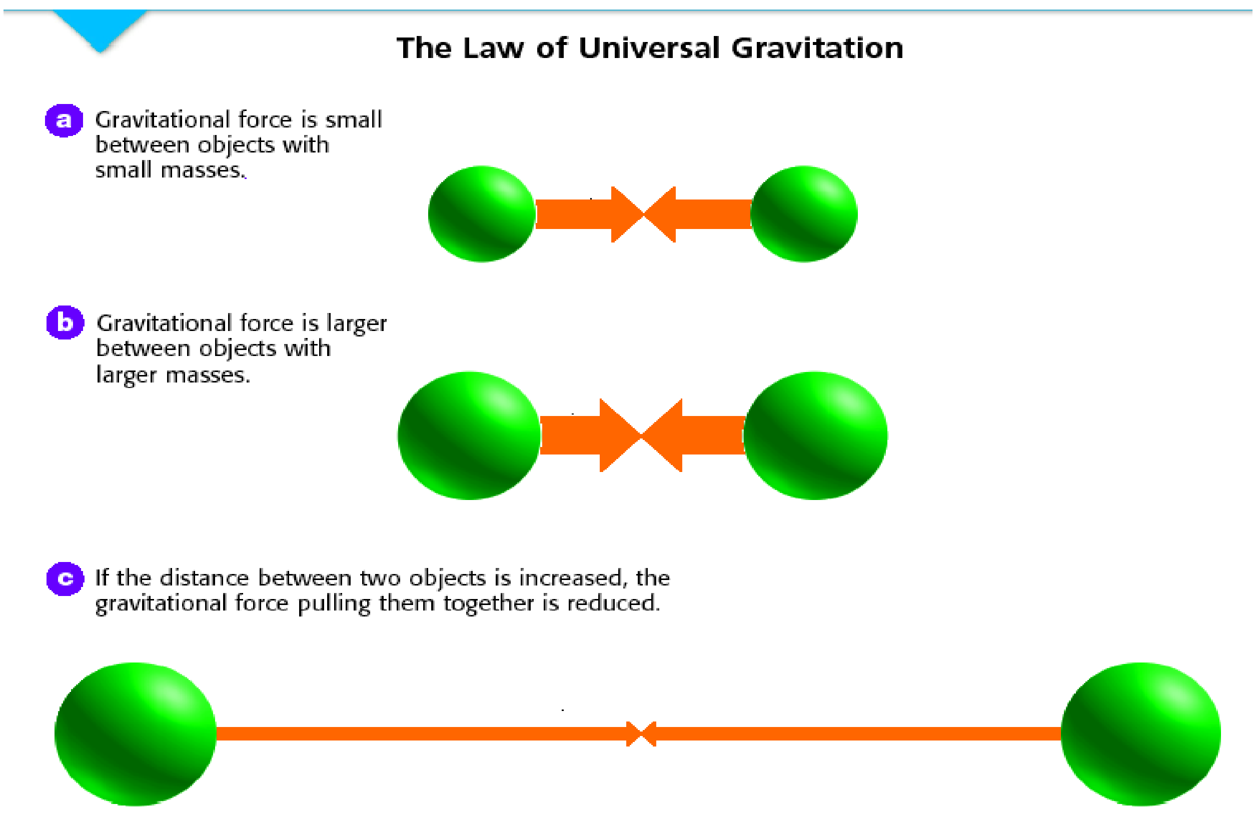
1- There is a mutual attraction force between the Moon and the

Earth that causes the rotation of the Moon around the Earth.

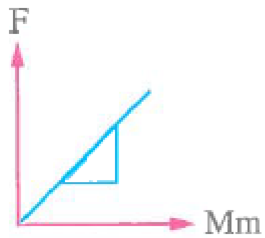
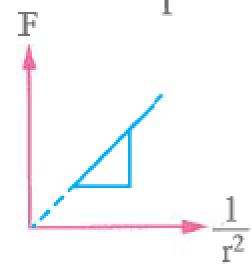
2- There is attraction force (gravitational attraction) between any two bodies in the universe and this force depends on:

1-The masses of two bodies (m , M)

2- The distance between the centers of 2 bodies (r)



The gravitational force (F_g) between two objects is directly proportional with the multiplication of two masses & inversely proportional with the square distance between them.

$F \propto Mm$  $\text{Slope} = \frac{\Delta F}{\Delta(Mm)} = \frac{G}{r^2}$	$F \propto \frac{1}{r^2}$  $\text{Slope} = \frac{\Delta F}{\Delta(\frac{1}{r^2})} = GMm$
$F \propto \frac{Mm}{r^2}$	

So the relation can be written as

$$\boxed{F = G\frac{mM}{r^2}}$$

Where (F): is the gravitational force

(m): is the mass of the first object

(M): is the mass of the second object

(r): is the distance between the two objects

(G): is the general (universal) gravitational constant

$(G) = F\frac{mM}{r^2} = 6.67*10^{-11}$ ($m^3/kg.s^2$ or $N.m^2/kg^2$)

The General (Universal) law

A body in the universe attracts another body by a force which is directly proportional to the product of their masses and inversely proportional to square the distance between their centers

Example 1:

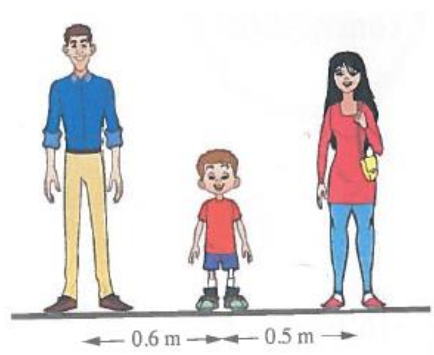
Find the mutual attraction force between the Sun and Jupiter given that the mass of the Sun is 2 $\times 10^{30}$ kg, the mass of Jupiter is 1.89 $\times 10^{27}$ kg and the distance between their centers is 7.73 $\times 10^{11}$ m. (knowing that : $G = 6.67 \times 10^{-11} N.m^2/kg^2$)

Solution: $m_s = 2*10^{30}$ kg $m_j = 1*10^{27}$ kg $r = 7.73 *10^{11}$ m

$$F = G\frac{mM}{r^2} = 6.67 \times 10^{-11} *2*10^{30}*1*10^{27}/(7.73 *10^{11})^2 = 4.22 * 10^{23} N$$

Example 2:

A child walks with his parents as in the opposite figure. If the masses of the child, his mother and his father are 30 kg, 65 kg and 80 kg respectively, calculate the mutual attraction force between each of the following by showing the effect of these forces on the child's motion path:



(a) The child and his mother.
(b) The child and his father.
(knowing that : $G = 6.67 \times 10^{-11} N.m^2/kg^2$)

Solution: m_1= (30 kg) m_2= (65 kg) m_3= (80 kg)

$$F_{12} = G\frac{m1M2}{r_{12}^2} = \text{..}$$

$$F_{13} = G\frac{m1M3}{r_{13}^2} = \text{..}$$

The mutual attraction force between the child and his parents is very small so we don’t notice it or feel it and it doesn’t affect the path of the child

Choose the correct answer:

1) Two moons A and B that have equal masses are rotating around a planet. If the radii of their orbitals are rand 2r respectively, then the attraction force of the planet with the moon B is ………………its attraction force with the moon A.

a) 4 times b) equal to c) half d) quarter

2) If the distance between the centers of two masses decreased to its half, the mutual attraction force between them is ………….

a) Increased 4 times b) is doubled
c) decreased to its half d) decrease to quarter

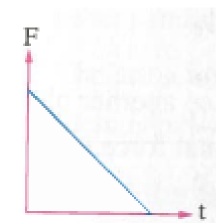
3) Two bodies of mass (m,) and (m,) and the distance between them is (r). If the mass of the first body is doubled and the distance between them is also doubled, the gravitational force between them ………………

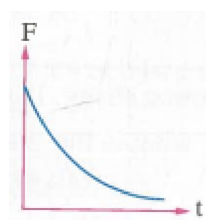
a) Increased 4 times b) is doubled
c) decreased to its half d) remains constant

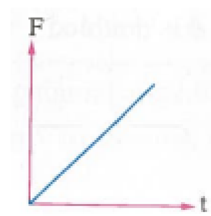
Exercise (3)

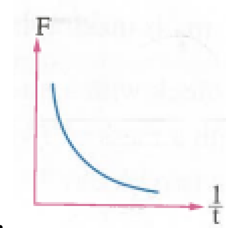
1) Choose the correct answer:

1) In the opposite figure : If the car is moving with uniform velocity away from the traffic lights, then what is the best graphical representation that represents the change of the gravitational force (F) between the car and the traffic lights with the time (t) is ……………….

a. 

b. 

c. 

d. 

2) If the distance between the centers of two identical balls is 1 m and the gravitational force between them is 1 N, the mass of each one of them equals …………………………

($G=6.67 \times 10^{-11} N.m^2/kg^2$)

a. 1 kg b. 1.22×10^5 kg c. 2×10^5 kg d. 0.1 kg

3) Two masses, m_1 and m_2 are separated by a distance d. What changes in the variables will result in no change in the gravitational force between the two masses? ……………… (Choose two answers)

a. m_1 is doubled and d is doubled

b. m_2 is quadrupled and d is doubled

c. m_2 is tripled and d is quadruple

d. Both m_1 and m_2 are tripled and d is tripled

4) Four planets A,B, C and D orbit the same star. The relative masses and distances from the star for each planet are shown in the table. For example, planet A has twice the mass of planet B and planet D has three times the orbital radius of planet A, Which planet has the highest gravitational attraction to the star?

Planet	Relative mass	Relative distance
A	2 m	r
B	M	0.1 r
C	0.5 m	2 r
D	4 m	3 r

a. Planet A b. Planet B c. Planet C d. Planet D

5) Two similar balls each of mass (m) and radius (r), placed in contact to each other, then the mutual attraction force between them is given by the relation ……………………..

a) F = $\frac{Gm^2}{r^2}$ b) F = $\frac{Gm^2}{4\,r^2}$

c) F = $\frac{2\,Gm^2}{r^2}$ d) F = $\frac{Gm^2}{2\,r^2}$

6) A satellite orbits the Earth at a distance of 100 km. The mass of the satellite is 100 kg while the mass of the Earth is approximately 6 x 10^{24}g and the radius of the Earth is approximately 6.4 x 10^6 m. What is the approximate gravitational force that acts on the satellite?

a. 4 x 10^4 N b. 4 x 10^8 N

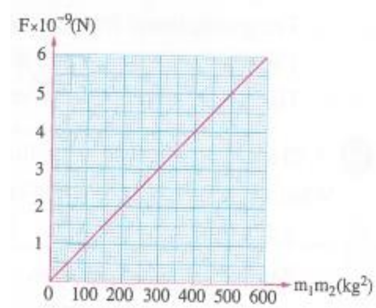
c. 6.2 x 10^6 N d. 9.5 x 10^2 N

7) Mars orbits the Sun at a distance of 2.3×10^{11} m. The mass of the Sun is 2×10^{30} kg and the mass of Mars is 6.4×10^{23} kg. Approximately what is the gravitational force that the Sun exerts on Mars?

a. 1.6×10^{20} N b. 1.6×10^{21} N

c. 3.7×10^{21} N d. 3.7×10^{32} N

8) The opposite graph represents the relation between the product of the masses of two bodies (m_1, m_2) and the gravitational force between them (F), so the distance between the two bodies (r) equals………



($G = 6.67 \times 10^{-11} N.m^2/kg^2$)

a. 1.84 m b. 2.58 m c. 4.62 m d. 5.78 m

9) If the gravitational acceleration due to gravity on the Moon’s surface is $\frac{1}{6}$ that on the Earth's surface, then the ratio between the universal gravitational constant on the Earth's surface to that on the Moon’s surface is ……..

a. $\frac{1}{6}$ b. $\frac{1}{3}$ c. $\frac{1}{1}$ d. $\frac{6}{1}$

10) Two satellites of equal masses orbit a planet. Satellite B orbits at twice the orbital radius of satellite A. Which of the following statements is true? ……………………

a. The gravitational force on satellite A is four times that on B

b. The gravitational force on satellite A is two times that on B

c. The gravitational force on the two satellites is equal

d. The gravitational force on satellite A is four times that on satellite B

11) The planet Jupiter orbits the Sun at a nearly constant speed. Which of the following statements are true? ………… (Choose two answers)

a. There is a force on Jupiter towards the center of the orbit

b. There is a force on Jupiter pulling it out from the center of the orbit

c. There is a force on Jupiter in the direction of its motion

d. Jupiter is accelerating towards the center of the orbit

12) A 70 kg astronaut floats at a distance of 10 m from a 50000 kg spacecraft. What is the force of attraction between the astronaut and spacecraft?

a. 2.4×10^{-6}N b. 2.4×10^{-5}N

c. Zero; there is no gravity in space d. 2.4×10^{5}N

<u>2) Explain each of the following statements:</u>

(1) The gravitational attraction is obvious among orbs.

………
………
………………………………………………

(2) The attraction force between two men at a distance of a few meters between each other cannot be detected.

………
………
………………………………………………

(3) The attraction force between two masses increases 4 times as the distance between them is halved.

………
………
………………………………………………

2) <u>What are the factors affecting</u> the attraction force between two bodies?

<u>Mention the law and the relation of proportionality.</u>

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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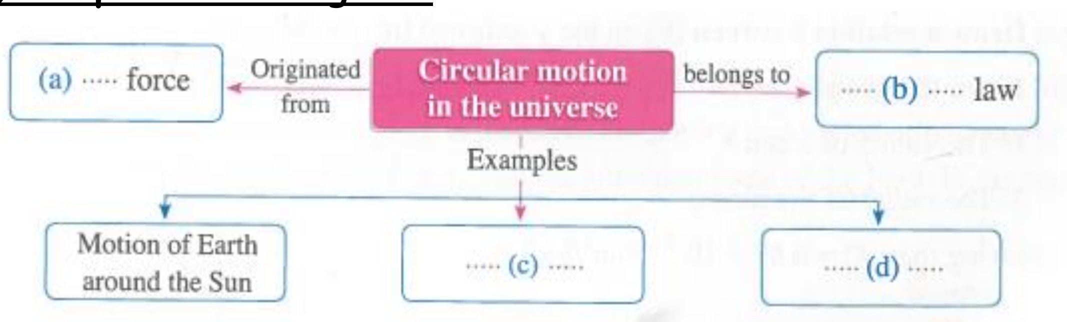
<u>3) Complete the diagram:</u>



<u>4) Problems:</u>

1) The center of the Moon is 3.9×10^5 km away from the center of the Earth. The mass of the Moon is 7.3×10^{22} kg and the mass of the Earth is 6×10^{24}kg. How far from the Earth's center an object is existed if the gravitational forces of the Earth and the Moon on the object are equal and opposite? (assume the object is on the line connecting the Earth and the Moon)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………………………………………………………………………………………*(3.5×10^5 km)*

2) A3kg mass is located 10 cm away from a 6 kg mass. What is the resultant gravitational force on a 2 kg mass located at the midpoint of a line joining the first two masses? (assuming that the masses behave as point masses)

………

………

……………………………………………………………………………………… *(1.6×10^{-7} N)*

3) Two balls having the same mass and the distance between their centers is 2 m and the attraction force between them is 6.67×10^{-9}N. Calculate the mass of each ball.

………

………

………………………………………………………………………………………… *(20 kg)*

4) Two bodies of masses 2 kg, 8 kg are separated by a distance of 20 cm, if the universal gravitational constant is 6.67×10^{-11} $N.m^2/kg^2$, Calculate the gravitational force between them.

………

………

……………………………………………………………………………………… *(2.67×10^{-8}N)*

Unit Three
Chapter 2
Lesson 2: (*Gravitational Field*)

The gravitational field:

The universal gravitational law states that the gravitational attraction between two bodies is inversely proportional to square the distance between their centers. Thus, the gravitational force decreases gradually as the distance increases till the distance between the centers of the two bodies reaches a point at which the attraction ceases.

Within this distance, there is a region in which the gravitational forces appear, this region is called the gravitational field

Deducing the Earth's gravitational field intensity (g):

By assuming that a body of mass 1 kg is placed in the Earth's gravitational field and at a distance r from the center of the Earth, then the attraction force of the Earth to the body

F = m.g ………..(1)

F = $G\frac{mM}{r^2}$ ………..(2) from 1 , 2 we find

m.g = $G\frac{mM}{r^2}$ **SO** $\boxed{g = G\frac{M}{r^2}}$

where g: is gravitational field $(\frac{F}{m})$

M = mass of Earth or sun (the object which we need to calculate the gravitational field on it)

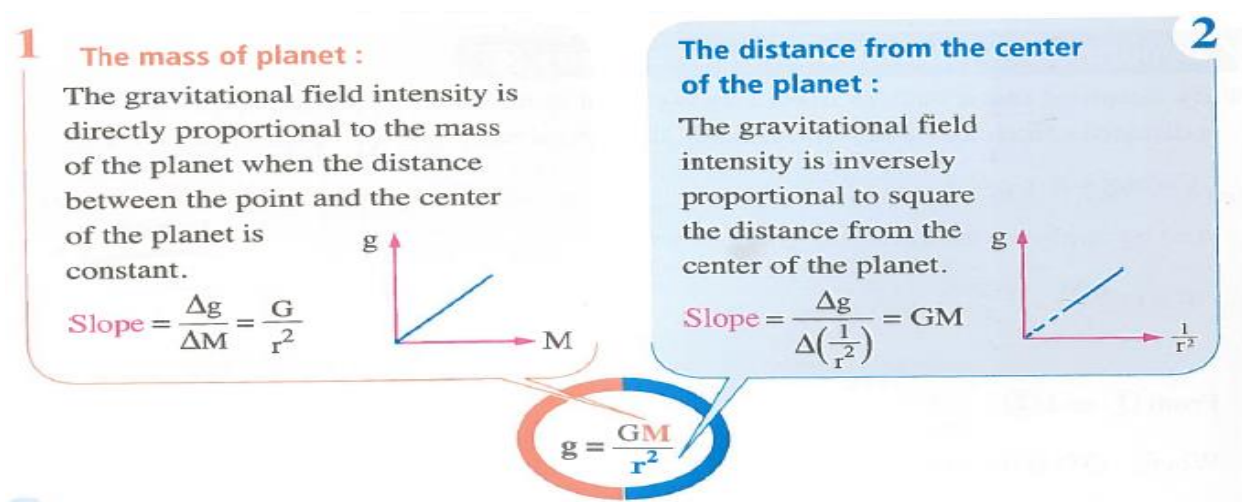
If the body is at		
1) The Earth's surface	2) At a height (h) above the Earth's surface	3) A depth (h) below the Earth's surface
g = $G\frac{M}{R^2}$	g = $G\frac{M}{(R+h)^2}$	g = $G\frac{M}{(R-h)^2}$
Where : (R) is the radius of Earth (6378 km) approximately		

To compare the acceleration due to gravity of two planets:

$$\frac{g_1}{g_2} = \frac{M_1 R_2^2}{M_2 R_1^2}$$

From the previous we notice that the gravitational field intensity at a certain point equals numerically the acceleration due to gravity of the Earth at this point.

Note: The gravitational field intensity varies slightly at Earth's surface because of the variation of the Earth's radius from one position to another where the Earth is not perfectly spherical but it is an oblate spheroid (a sphere that is squashed at its poles and swollen at the equator) and that is due to the centripetal force that originates from the rotation of the Earth around itself.



Example 1:

A satellite of mass 10^4 kg orbits the Earth at a height of 600 km from its surface, calculate:

(a) The acceleration due to gravity of the Earth that affects the satellite on its orbit.

(b) The weight of the satellite in its orbit.

(knowing that : R = 6378 km, M = 5.98 x 10^{24}kg,G = 6.67 x10^{-11} N.mlkg)

Solution: m=10^4 kg R=6378 km h=600 km

i) $g = G\frac{M}{(R+h)^2} = \frac{6.67\ x10^{-11} * 5.98\ x10^{24}}{((6378+600)*10^3)^2}$ = 8.19 N / kg

ii) w = m.g = $10^4\ x$ 8.19 = 8.19 $*$ 10^4 N

Example 2:

A planet has a mass twice that of Earth and a diameter twice that of Earth. Find the ratio between the acceleration due gravity on the planet and the acceleration due to gravity on Earth.

Solution: $M_p= 2\ M_E$ $R_p=2R_E$ $\frac{g_p}{g_E}$ = ???

$$\frac{g_p}{g_E} = \frac{M_p R_E^2}{M_E R_p^2} = \frac{2M_E R_E^2}{4M_E R_E^2} = \frac{1}{2}$$

Exercise 4

1) Choose the correct answer:

1) Two asteroids in the space are close enough to each other. Each has a mass of 6.69×10^{15}g. If they are 100000 m apart, what is the gravitational acceleration that they experience?

a. 3.89×10^{10} m/s^2 b. 2.99×10^{11} m/s^2
c. 5.12×10^{4} m/s^2 d. 4.46×10^{-5} m/s^2

2) The mass of Mercury is 3.3×10^{23}kg and its radius is 2.439×10^{6}m. If a body of mass 65 kg is placed on Mercury's surface, then……………… (Choose two answers)

(Knowing that: the acceleration due to gravity on Earth's surface is 9.8 m/s^2 and the general gravitational constant is 6.67×10^{-11}N.m^2/kg^2)

a. the weight of the body on Mercury's surface is 240.5 N
b. the weight of the body on Mercury's surface is 637 N
c. the weight of the body on Mercury's surface is 320.5 N
d. the mass of the body on Earth's surface is 65 kg
e. the mass of the body on Earth's surface is 172 kg

3) An object has a mass of 50 kg and a weight of 500 N when it is resting on the surface of the Earth. If it is moved to a height equal to three times the Earth's radius, what is the object's new weight?

a. 300 N b. 31.25 N c. 130 N d. 60.5 N

4) Which of the following affect the strength of the gravitational field on the surface of a planet? (more than one answer is correct)

a. The mass of the object at the surface
b. The mass of the planet
c. The radius of the planet
d. The presence of air at the surface of the planet

5) When climbing from the sea level to the top of mount Everest, a hiker changes elevation by 8848 m. By what percentage will the gravitational field of the Earth change during the climb?
(where the Earth's mass is 6×10^{24}kg and its radius is 6.4×10^{6} m)

a. I will increase by approximately 0.3 %
b. It will decrease by approximately 0.3 %
c. It will increase by approximately 12 %
d. It will decrease by approximately 12 %

6) IF R is the radius of the Earth, so the height at which the weight of a body becomes $\frac{1}{4}$ its weight on the surface of the Earth is …………

a. 2R b. R c. $\frac{R}{2}$ d. $\frac{R}{4}$

7) Assign the acceleration of the Moon the symbol a_m and the mass of the Moon M_m. If a satellite with a mass M_s was placed in the same orbit of the Moon at the same speed, what is the gravitational field strength at the satellite's orbit? ………….

a. a_m b. $(M_s/M_m)a_m$ c. $(M_. M_s)a_m$ d. $(M_s+M_m)a_m/M_s$

8) If the acceleration due to gravity of the Earth at the orbit of a satellite that orbits the Earth is 2.5 m/s^2, then the distance between the satellite and the Earth's surface (h) equals …………..
(where: R the radius of the Earth and the acceleration due to gravity at the Earth's surface = 10 m/s^2)

a. 2 R b. R c. $\frac{R}{2.5}$ d. $\frac{R}{4}$

9) A planet of mass 5.98×10^{24}kg and radius 6378 km. If G = 6.67 $\times 10^{-11}$N.m^2/kg^2, so the intensity of the planet's gravitational field at a point that lies at a distance 36000 km from its surface equals ……N /kg.

a. 22.2×10^{4} b. 22.2×10^{2} c. 22.2×10^{-2} d. 22.2×10^{-4}

2) What are the factors on which each of the following depends? Mention the law and the relation of proportionality.

(a) The acceleration due to gravity on a planet.

……

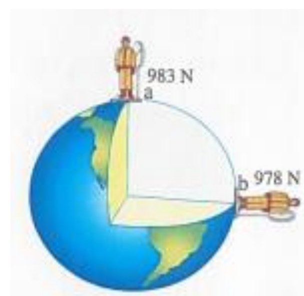
……

(b) The gravitational field intensity of the Earth.

……

……

3) In the opposite figure, **explain why** is the weight of the man at the points a and b different?



……

……

4) What is the difference between the gravitational field and the gravitational field intensity.

……

……

5) When the gravitational field intensity and the acting force equalize?

……

……

6) Imagine that the Earth starts to shrink uniformly while its mass remains constant. **What would happen to** the value of the acceleration due to gravity on its surface?

....

....

7) Problems:

1) Calculate the ratio between the acceleration due to gravity on the Moon and that on the Earth, knowing that:

• Mass of Earth 5.976×10^{24} kg and its radius 6.4×10^{6} m.

• Mass of Moon 7.35×10^{22} kg and its radius 1.74×10^{6} m.

....

....*(0:1664)*

2) If the radius of a planet is 7.14×10^{7} m and its mass is 1.9×10^{27}g and $G=6.67 \times 10^{-11} N.m^2/kg^2$, find:

(a) The attraction force acting on an object of mass 1 kg at the planet's surface.

....

....

(b) The acceleration due to gravity on the planet's surface.

....

.... *(24.86 N, 24.86 m/s²)*

3) An object is dropped with no initial velocity, above the surface of planet Big Alpha and falls 13 .5 meters in 3 seconds, the radius of planet Big Alpha is 5.82×10^{6} meters.

(a) What is the acceleration of the falling object.

....

....

(b) What is the mass of planet Big Alpha.

……

………………………………………………………………………………… *(3 m/s^2,152 x 10^{24}kg)*

4) On a distant planet, the acceleration due to gravity is 5 m/s^2 and the radius of the planet is roughly 4560 km. Use the law of gravitation to estimate the mass of this planet.

……

………

(1.56 x 10^{24}kg)

5) A planet of mass 5 times the mass of the Earth and its diameter 5 times that of the Earth. Calculate the ratio of the acceleration due to gravity on Earth's surface to that on the planet.

……

……………………………………………………………………………………………………… $(\frac{5}{1})$

6) The mass of the Earth is about 81 times the mass of the Moon. If the radius of the Earth is four times that of the Moon, what is the acceleration due to gravity on the Moon?

……

………$(\approx \frac{5}{1} g_e)$

7) If the mass of the planet Mercury is 3.3 x 10^{23} g and its radius is 2.439 x 10^6 m, what is the weight of a body of mass 65 kg on Mercury and what is the weight of the same object on the Earth (knowing that: $G = 6.67 \times 10^{-11}$N.m^2/kg^2)?

……

………………………………………………………………………………………*(240.5 N, 637 N)*

Unit Three
Chapter 2
Lesson 3: (*Satellites*)

A satellite in its orbit is considered as an object that falls freely towards the Earth's surface (because it is under the effect of Earth's gravity), in spite of this it never reaches the Earth's surface. Isaac Newton explained this where he imagines that when projecting a cannon projectile from the top of a mountain in a horizontal direction (neglecting the air resistance) :

The projectile moves through a certain horizontal distance before falling freely on the ground where it moves in a curved path towards the Earth.

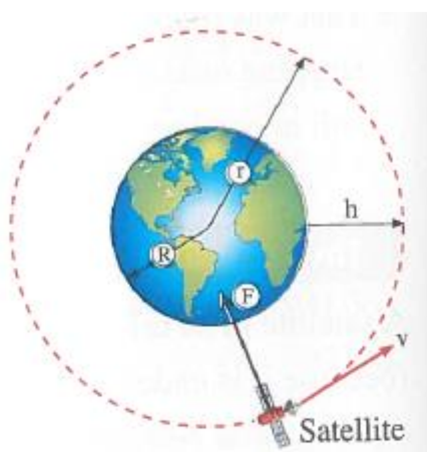
The orbital velocity of a satellite:

It is the velocity that makes the satellite orbit the Earth in a roughly circular path where its distance from the Earth's surface is kept constant.

Deducing the orbital speed of the satellite (v)

Assume that a satellite of mass (m) moves with a velocity (v) in an orbit of radius (r) around the Earth of mass (M) as in figure :
The force of attraction between the Earth and the satellite is given by the relation :

F = $G\frac{mM}{r^2}$



The force of attraction between the Earth and the satellite is normal to the direction of the motion of the satellite so it makes the satellite move in a circular path: $F_c = m\frac{v^2}{r}$

So the attraction force between the Earth and the satellite is the same centripetal force that acts on the satellite.

$G\frac{mM}{r^2} = m\frac{v^2}{r}$ so $v^2 = G\frac{M}{r}$

$$\boxed{V = \sqrt{G\frac{M}{r}}}$$

Where v : is the velocity of the satellite

G = Universal gravitational const.

M = The mass of the planet which the satellite moves around

r = the distance between the center of the planet & satellite

Note:

If the satellite was launched to height (h) from the Earth and the radius of the Earth is R then r = R+h so the velocity will be:

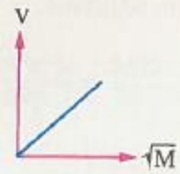
$$V = \sqrt{G\frac{M}{R+h}}$$

The factors affect the orbital speed of satellite:

1 **The mass of the planet :**

The orbital velocity of a satellite is directly proportional to the square root of the mass of the planet at constant radius of the orbit.

$$\text{Slope} = \frac{\Delta v}{\Delta \sqrt{M}} = \sqrt{\frac{G}{r}}$$



2 **The radius of the orbit :**

The orbital velocity of a satellite is inversely proportional to the square root of the radius of the orbit.

$$\text{Slope} = \frac{\Delta v}{\Delta\left(\frac{1}{\sqrt{r}}\right)} = \sqrt{GM}$$

$$v = \sqrt{\frac{GM}{r}}$$

Notes:

1. If we imagine that a satellite stopped suddenly while rotating around the Earth (its velocity became zero), so the satellite will move in a straight line towards the Earth under the effect of the Earth's gravity and falls down on its surface.

2. If we imagine that the gravitational force between the Earth and a satellite vanished, so the satellite will move in a straight line tangent to the circular path away from the Earth.

3. The satellite that is synchronized with the rotation of the Earth (follows the Earth) has a periodic time that is equal to the periodic time of the Earth's rotation around itself during one solar day (24 hours), so the satellite remains above a constant point on the Earth's surface.

4- We can calculate the Orbital speed of the satellite as follows :

a) By knowing the periodic time	V= $\frac{2\pi r}{T}$
b) By knowing the frequency	V= $2\pi r . f$
c) By knowing the mass of planet (relation between (V & r) can be known from this equation only) V is inversely prop. to $\sqrt{r}$	V= $\sqrt{G\frac{M}{r}}$
d) By knowing the gravitational field intensity	V= $\sqrt{g . r}$

5- We can deduce the relation between the radius (r) of the orbit of a satellite that orbits a planet and the periodic time of its motion (T) as follows:

V= $\frac{2\pi r}{T}$ & V= $\sqrt{G\frac{M}{r}}$ so $\frac{2\pi r}{T} = \sqrt{G\frac{M}{r}}$ square both sides

$\frac{4\pi^2 r^2}{T^2} = G\frac{M}{r}$ so $\frac{4\pi^2 r^3}{G.M} = T^2$ but π, G, M are const.

So $T^2 \propto r^3$

T^2 is directly proportional with r^3

6- the orbital speed of satellite doesn't depend on the satellite's mass.

7- The orbital velocity of a satellite that orbits the Earth is inversely proportional to the square root of the radius of the orbit according to the relation V= $\sqrt{G\frac{M}{r}}$

<u>**So we can't say that the orbital velocity:**</u>

1) is directly proportional to the radius of the orbit from the relation $V = \frac{2\pi r}{T}$ because the periodic time also depends on the radius of the orbit from the relation $\frac{4\pi^2 r^3}{G.M} = T^2$

2) is directly proportional to the square root of the radius of the orbit according to the relation ($V=\sqrt{g.r}$) because the gravitational field intensity also depends on the radius of the orbit from the relation ($g = G\frac{M}{r^2}$).

<u>Example 1:</u>

The Moon rotates around the Earth in a circular orbit of radius 3.85 x 10^5 km and completes one revolution in 27.3 days. Calculate the mass of the Earth. (knowing that : Universal gravitation constant = 6.67 x 10^{-11} $m^3.kg^{-1}.s^{-2}$, π =3.14)

<u>Solution</u>: r = 3.85 x 10^8 m T= 27.3 x 24 x 60 x 60 sec

$$V = \frac{2\pi r}{T} = \frac{2\pi \times 3.85 \times 10^8}{2358720} = 1.022 \times 10^3$$

$$V^2 = G\frac{M}{r} \text{ so } M = \frac{r.v^2}{G} = \frac{3.85 \times 10^8 * (1.022*10^3)^2}{(6.67*10^{-11})} = 60.71 \times 10^{24} \text{ Kg}$$

Example 2:

A satellite rotates around the Earth in a roughly circular orbit at a height of 940 km above the Earth's surface. Calculate the orbital velocity and the time required by the satellite to make a complete revolution around the Earth. (knowing that : R = 6360 km, M = 6 x 10^{24} kg, G=6.67 x 10^{-11} $m^3.kg^{-1}.s^{-2}$, π =3.14**)**

Solution: h= 940 km R = 6360 km M = 6 x 10^{24} kg

$$V=\sqrt{G\,\frac{M}{R+h}} = \sqrt{\frac{(6.67*10^{-11})\,(6*10^{24})}{(6360+940)*10^{3}}} = 7.4 \times 10^{3}\ m/s$$

$$T = \frac{2\pi\ r}{v} = \frac{2\pi\ (6360+940)}{7.4 \text{ x } 10^{3}} = 6195.14\ s = 1.72\ h$$

Example 3:

A satellite orbits the Earth in a constant orbit. If a part that represents quarter the mass of the satellite separates from the satellite, then the orbital velocity of the satellite ………………………………………………

a) decreases to quarter its original value

b) increases four times

c) increases by a quarter of its original value

d) remains constant

Solution: - The orbital speed of satellite doesn't depend on the satellite's mass. So the answer is (d)

The importance of satellites:

The satellite is considered as a very high tower that can be used in transmitting and receiving the wireless waves.

<u>Satellites can be classified according to their applications into:</u>

1- Communication satellites, used in :

a) TV transmission. b) Radio transmission.

c) Phone calls. d) Monitor regions using Google Earth

e) Locating sites through GPS. F) Internet.

2- Astronomical satellites :

They are huge telescopes floating in the space. They can be used to photograph the space accurately.

3- Remote sensing satellites, they are used to:

a) Study and monitor the emigrant birds.

b) Determine the mineral resources and their distributions underground.

c) Look out for the agricultural yields to protect them against weather dangers.

d) Study the formation of hurricanes.

4- Explanatory and spying satellites:

They abound the information needed by military and political leaders to make decisions and war administration.

5-Weather satellites:

They are used to monitor weather and climate of the Earth by taking photographs for the atmosphere from a height of 35000 km from the surface. They track hurricanes and monitor the atmospheric conditions like air quality, clouds and ice glaciers.

Exercise 5

Choose the correct answer:

1) Orbital velocity that is required to keep a satellite rotating around a planet depends on the……………………. (Choose two answers)

a) mass of the satellite

b) mass of the planet

c) distance between the centers of the planet and the satellite

d) periodic time of the satellite's rotation around the planet

e) direction of the satellite's rotation around the planet

2) The orbital velocity of a satellite is inversely proportional to .... •

a) the mass of satellite (b) the square root of its mass

c) the radius of the orbit d) the square root of the orbital radius

3) Two satellites A and B rotate around the Earth. If the orbit radius of satellite A equals 4 times the orbit radius of satellite B. So, the ratio between the velocity of satellite A to that of satellite B equals............

a) 2:1 b) 4:1 c) 1:2 d) 1:4

4) Two satellites having the same orbital radius, one rotates around the Earth and the others rotates around Mars. If the mass of Earth is nine times that of Mars, then the ratio between the linear speed (tangential) of the satellite rotating around the Earth to that rotating around

Mars equals ………………………

a) 1:9 b) 9:1 c) 1:3 d) 3:1

5) A satellite orbits the Earth at a height (h) from the Earth's surface with an orbital velocity of $\frac{1}{2}\sqrt{\frac{GM}{R}}$ where R is the radius of the Earth, then the distance between the satellite and the surface of the Earth (h) is ……………………

a) R b) 2R c) 3R d) 4R 5) R

6) A satellite orbits the Earth at a distance of 200 km. If the mass of the Earth is 6×10^{24}kg and the Earth's radius is 6.4×10^{6} m, what is the satellite's speed?.................

a) 1×10^{3} b) 3.5×10^{3} c) 7.8×10^{3} d) 5×10^{6}

7) A satellite rotates at height 12000 km from a planet of mass 9.96×10^{22} g. If the radius of the planet is 1063 km and $G = 6.67 \times 10^{-11}$ Nm^2/kg^2 so, the orbital velocity of the satellite= .... m/s

a) 744 b) 713.13 c) 311 d) 249.9

8) Phobos, a moon of the planet Mars, whose orbital radius is 9380 km and its orbital period is 0.319 days (2.77×10^{4} seconds). The mass of Mars based on this data is .... (where : $G = 6.67 \times 10^{-11}$ Nm^2/kg^2)

a) 6.37×10^{23}kg b) 1.36×10^{15}kg

c) 9.21×10^{34}kg d) 3.23×10^{27}kg

9) The orbital radius of two satellites rotating around a planet are 2×10^{6} m and 1×10^{6} m respectively. If the periodic time of the second satellite is 8×10^{7} s , then the periodic time of the first equals ……………

a) 5×10^{5}s b) 4×10^{6}s

c) 2.3×10^{8}s d) 4.5×10^{8}s

10) Two satellites are at the same distance from the Earth. If one of the satellites has a mass of m and the other has a mass of 2 m, which one will have the smaller acceleration? ……………………………….

a) m b) They both will have the same acceleration
b) 2m d) Neither will have an acceleration

Second Problems:

1) satellite of mass 100 kg moves around the Earth in a roughly circular path of radius 7.4 3x 10^6 m with a speed of 7.4 x 10^3 m/s, calculate the attraction of Earth on the satellite.

………
…….(740N)

2) A satellite rotates in an orbit at height (h) 300 km from the Earth's surface. Find:

(a) The orbital velocity.

(b)The periodic time of the satellite around the Earth.

(c) The centripetal acceleration of its motion.

(knowing that : radius of the Earth 6378 km , acceleration due to gravity at the Earth's surface = 9.8 m/s^2)

………
………
………
……………………………………………………………….(8.09x 10^3 m/s, 5.18x 10^3 s,9.8 m/s)

3) How high above the Earth's surface should a satellite rotate so that its periodic time around the Earth equals the periodic time of the Earth's spinning knowing that:

• Earth's day= 24 hour

• Mass of the Earth (M_E) = 5.98x10^{24}kg, universal gravitational constant (G) =6.67 x 10^{-11}Nm^2/kg^2,radius of the Earth (R) = 6378 km

………
……………………………………………………………………………………………………….(3.6x10^7 m)

4) A planet of the same mass of the Earth has a radius double the radius of the Earth. What is the weight of a body on this planet's surface if its weight on the Earth's surface is 100 N?

....

....

....(25 N)

5) A planet has a mass four times the mass of the Earth and a radius double the radius of the Earth, calculate the weight of the body on this planet if its weight on the Earth is 150 N.

....

....

....(150 N)

6) the mass of the Earth is 81 times the mass of the Moon and the distance between the center of the Earth and the center of the Moon is 60 R. So on what distance from the center of the Moon will the point (x) be located? Where the resultant of the gravitational fields of each of the Moon and the Earth at point (x) equals zero and R = 6378 km

....

....

....(38268 km)

Unit Four

Chapter 1

Lesson 1: (*Work*)

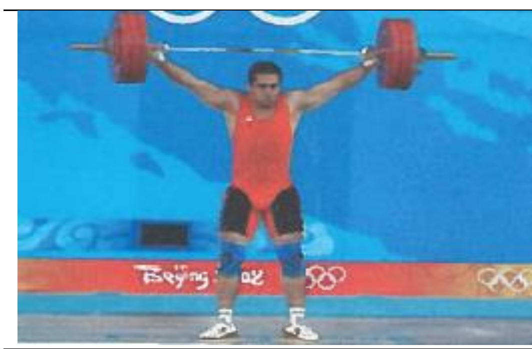
The meaning of work in Physics is different from that used in everyday life. Work does not mean that a tough task is done. To do work on a body, the body must move a certain displacement due to the force acting on it. If the body doesn't move, so there is no work done whatever the value of the force acting on the body.

In Physics, there are two conditions for work to be done:

(1) Applying force to the body.

(2) Moving the body for some displacement in the direction of force action.

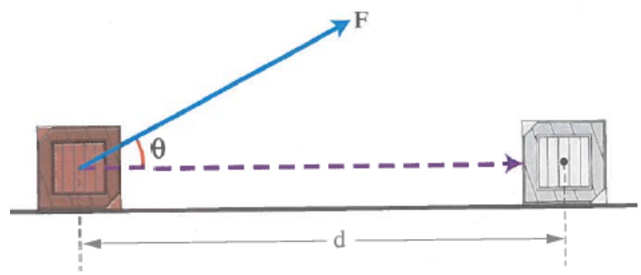
This can be illustrated by the following two examples:

1- The player who lifts weights up does work.	2. The person who pushes the wall does no work.
	
The force acting on the weights moves them upwards through a distance in the direction of the force.	The force acting on the wall fails to move it. The wall remains motionless.

Conclusion: When a force acts on an object to move it through a certain displacement in the direction of the line of action of the force, it is said that the force does work. But if the object doesn't move then no work.

So Work (w) can be determined from the relation:

$$W = \vec{F} . \vec{d} = |F|\ |d|\ \cos\theta$$



F: is the acting force on a body

d: the displacement of the body due to the action of the force.

θ: The angle between the direction of the acting force & the direction of the displacement.

Work can be measured in joule (N.m) or ($Kg.m^2/s^2$)

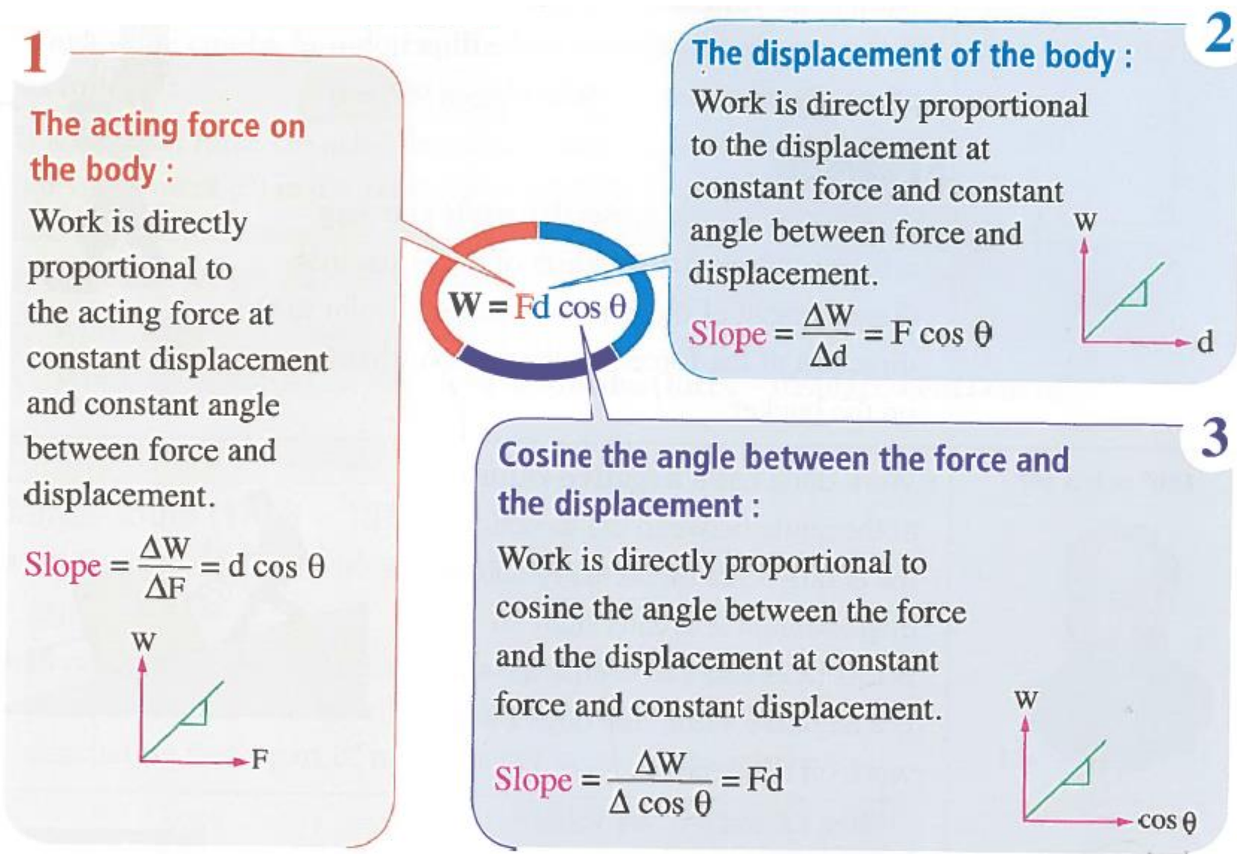
Work: is the dot product of the acting force (F) and the displacement (d) in the direction of the line of action of the force.

Joule: It is the work done by a force of 1 N to move an object through a displacement of 1 m in the direction of the line of action of the force.

Note: Although both force and displacement are vector quantities, work is a scalar quantity. Because work is the dot product of the force and the displacement.

Example : The work done to move a cart 5 m forward is the same work done to move the cart 5 m backward.

The factors that affect work done to a body:



$W = Fd \cos\theta$

1 The acting force on the body :

Work is directly proportional to the acting force at constant displacement and constant angle between force and displacement.

$\text{Slope} = \dfrac{\Delta W}{\Delta F} = d \cos\theta$

2 The displacement of the body :

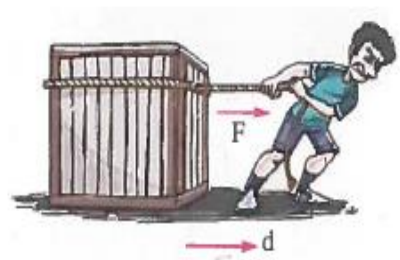
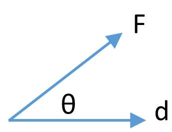
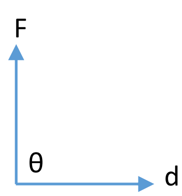
Work is directly proportional to the displacement at constant force and constant angle between force and displacement.

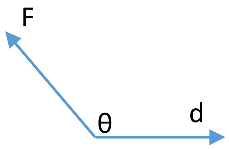
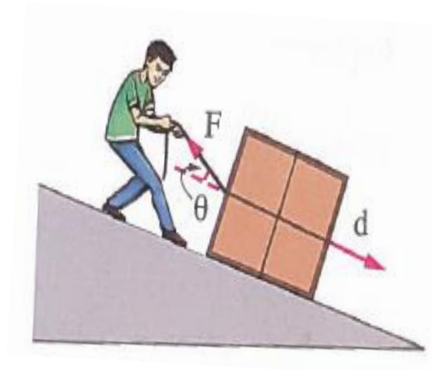
$\text{Slope} = \dfrac{\Delta W}{\Delta d} = F \cos\theta$

3 Cosine the angle between the force and the displacement :

Work is directly proportional to cosine the angle between the force and the displacement at constant force and constant displacement.

$\text{Slope} = \dfrac{\Delta W}{\Delta \cos\theta} = Fd$

angle (θ)	The work done	Example
$\Theta=0$  W = +ve (maximum)	Work done has a maximum positive value when the direction of the force is in the same direction of the displacement. $W = \lvert F \rvert \lvert d \rvert \cos\theta = Fd$	
$0^{o} < \Theta < 90^{o}$  W = +ve	Work done has a positive value due to the angle between the direction of the acting force on the body and the displacement is less than 90°, so cosine the angle is a positive value (the person does work on the object). As angle increased from 0^{o} to $90^{o}$the cosine of the angle decreased, the work decreased.	
$\Theta=90^{o}$  W = zero	Work done vanishes (zero) when the direction of the force is perpendicular to the direction of displacement. $W = \vec{F}.\vec{d} = \lvert F \rvert \lvert d \rvert \cos\theta$ A person moves horizontally while carrying a bucket where the direction of the horizontal displacement of the person is perpendicular to the direction of the force that the person's hand exerts on the bucket.	

180 > θ > 90  W = -ve	Work done has a negative value due to the angle between the direction of the acting force on the body and the displacement is greater than 90° and is less than 180°, so cosine the angle is a negative value (**the object does work on the person**). Ex. Person pulling an object while the object is moving opposite to the direction of the force. As angle increased from 90° to 180° the cosine of the angle increased, the work increased.	
θ = 180  W = -ve maximum	Work done has a maximum negative value when the direction of the acting force on the object is opposite to the direction of its displacement. $W = F|\,|d|\ \cos\theta = -Fd$	

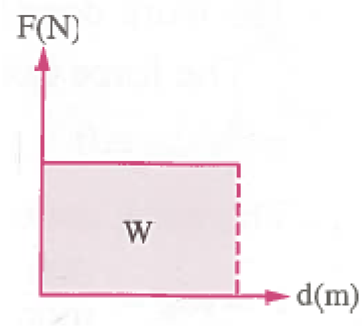
Example 1:

A satellite doesn't require any fuel to be consumed for orbiting the Earth because no work is done on the satellite as the acting force …………

a) In the same direction of motion c) perpendicular to its motion

b) In the opposite direction of motion d) equal zero

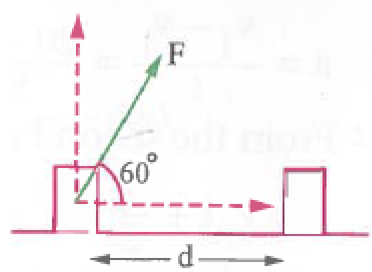
Finding the work done graphically:
relation between force & displacement

If a constant force (F) acted on a body and displaced it through a displacement (d) in the same direction of the force then ($\theta = 0°$) and when representing the relation (force versus displacement) graphically, we get the opposite graph: Work = Force x Displacement So the work can be calculated by calculating area under the curve.	

Example 2:

A cart of mass 20 kg is pulled by a force of 50 N. The line of action of the force makes an angle of 60° to the direction of displacement. Find the work done by the force to displace the cart through 4m

Solution: m= 20 kg F= 50 N θ= 60° d=4m



$W = Fd \cos\theta$

$W = (50)(4) \cos 60 = 100$ j

<u>Example 2:</u>

Calculate the work done by a girl on a bucket of mass 300 g that is carried by her through a displacement of 10 m in the horizontal direction. Then, calculate the work done by a boy to lift a bucket of the same mass through a displacement of 10 cm in the vertical direction. (where : $g = 10\ m/s^2$, the force of tension = The bucket's weight)

Solution: m= .3 kg g= 10 m/s d=10 cm

Weight = .3 x 10 = 3 N (direction of weight is downward)

- At the horizontal Work θ =90 because the displacement ⊥ F (weight)

The horizontal work = zero

- At vertical work θ = 0 because the tension of the rope is upwards and the displacement in the same direction so the work = Fd = 3 x 0.1 = 0.3j

Example 3:

A force of 100 N acts on a static body to move it horizontally. If the body's velocity reaches 20 m/s after 5 s, calculate the work done by this force after 5 s from the start motion neglecting the friction forces.

Solution: F=100 N v_i=0 v_f=20 t=5

Vf = vi + at = 20 = 5a so a = 4 m/s^2

d= vit +0.5 at^2 = d= (0.5)(4)(25) = 50 m

Work = Fd = 100 x 50 = 5000 j

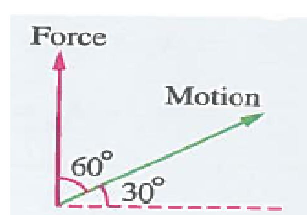
Example 4:

A worker that carries a box of mass 40 kg climbs up stairs of length 20 m as shown in the figure. If the free fall acceleration equals 10 m/s^2 find the work done on the box.

Solution: m= 40 kg d= 20 m g=10 m/s^2

The direction of the weight is to upward

So the angle between the stairs(displacement) & the force is 90 - 30 =60°



W= Fdcos θ = 400 x 20 x cos 60 = 4000 j

Exercise 6

Choose the correct answer:

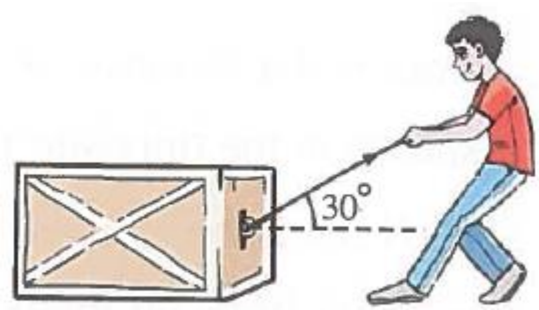
1) Joule is equivalent to ……………………

a) N.m b) N/m c) $Kg.m^2/s^2$ d) kg.m/s

2) The work done is maximum when the angle between the direction of the force that acts on a body and the direction of its displacement equals ……………………………

a) zero b) 45° c) 60° d) 90°

3) when a box moves in a direction that makes an angle 30° with the direction of the force acting on it as in the opposite figure, then the work done on the box by this force will be …………………



a) Zero c) half the maximum value

b) Maximum d) $\frac{\sqrt{3}}{2}$ the maximum value

4) The work is negative if the direction of the displacement ……… direction of the force.

a) is in the same b) is normal to the

c) opposes the d) is inclined by an acute angle

5) In the car, the work done by the brakes ....

a) is positive b) is negative

c) equals zero d) may be positive or negative

6) If the force acting on a body is doubled such that the body covers the same displacement, then the work done ……………………………

a) increases 4 times b) decreases to its half

c) is doubled d) remains constant

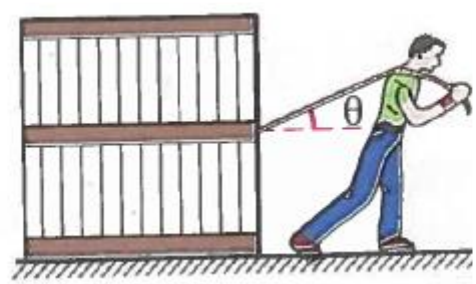
7) A body moves in a uniform circular motion under the effect of a resultant force of 40 N. If the body covered a displacement of 10 m, then the work done on the body equals ………………………………

a) zero b) 4J c) 40J d) 400J

8) A child of mass 40 kg moves horizontally on a skating surface, then the work done by his weight when he moves a distance of 20 m/s..........

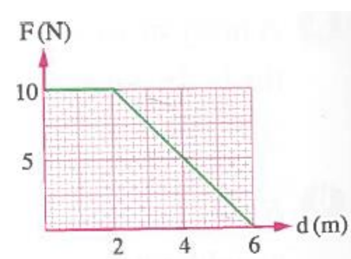
a) zero b) 800J c) 4000J d) 8000J

9) The opposite figure shows a man that pulls a box with a force (F) to displace it a displacement (d), so the magnitude of the work done by the man on the box decreases by…………..
(Choose two answers)



a) decreasing the acting resultant force on the box
b) increasing the acting resultant force on the box
c) decreasing the angle between the force and the displacement
d) increasing the angle between the force and the displacement
e) increasing the magnitude of the displacement moved by the box

10) The opposite graph shows the relation between the horizontal force that acts on a body and the horizontal displacement covered by the body due to this force, then the work done by this force is …………………..

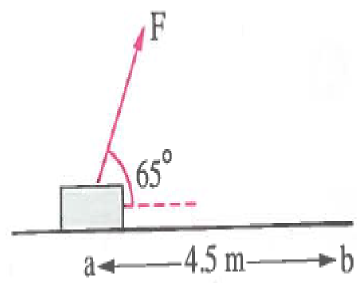


a) 20 J b) 40 J c) 50 J d) 60 J

11) A mother pushes her child's cart with a constant velocity on a straight horizontal road by a force that makes with the horizontal an angle of 60°. If a friction force of 20 N acts on the cart, then the work done by the mother to move the cart a distance of 5 m equals ……………………………….

a) 100 J b) 80 J c) 50 J d) 40 J

12) A body of mass 5 kg is placed on a smooth horizontal plane. A force of 40 N acts on the body to move it from rest a distance of 4.5 m from point a to b as shown in the opposite figure. If the friction force is 15 N, then the (Choose two answers)



a) work done on the body by the force during its motion from a to b equals zero

b) work done on the body by the force during its motion from a to b equals 8 .6 J

c) work done on the body by the force during its motion from a to b equals 112.5 J

d) velocity of the body at b equals 1.85 m/s

e) velocity of the body at b equals 10.6 m/s

<u>Second Problems:</u>

1) Find the work done to push a cart by a force of 20 N through a displacement of 3 .5 m.

………
………
………………………………………………………………………………………………………(70J)

2) A force of 100 N acts on an object to displace it through 2.5 m.

Find the work done by this force in the following cases:

(a) If the force acts in the same direction of the object's motion.

(b) If the force's direction makes an angle of 60° with the direction of the object's motion.

(c) If the force acts perpendicular to the direction of the object's motion.

………

………

………………………………………………………………………………………(250J, 125 J, 0)

3) A motorcycle of mass 200 kg moves in a straight line under the effect of the motor's force of 500 N. If the frictional force is 100 N for every 100 kg of the motorcycle's mass, calculate the work done on the motorcycle to move it a distance of 50 m.

………

………

…………………………………………………………………………………………………(15000 J)

4) A force of 200 N acts on a static object of mass 50 kg to move it in its direction. Calculate the work done by this force during 5 seconds.

………

……………………………………………………………………………………………………(10^4 J)

5) In the opposite figure, a man of mass 70 kg climbs upstairs of length 50 m. Calculate the work done if g = 10 m/s

………

………

……………………………………………………………………………………………30.31×10^3 J

Unit Four
Chapter 1
Lesson 2: (*Energy*)

Man needs energy to exert effort (do work) and without energy no task can be performed.

For example: When a person kicks a ball, the chemical energy stored inside his body is converted into another form of energy which causes the movement of the ball.

Energy: is the capacity (ability) for doing work.

Energy can be measured in joule or N.m ($Kg.m^2/s^2$) & D.F = ML^2T^{-2}

The forms of energy :

1- Kinetic energy

2- Potential energy

First Kinetic energy:

When work is done to move an object, this work gets acquired by the object as kinetic energy.

Examples (A man running, a car moving, water falling, elc….)

Deduce the kinetic energy of an object:

If a force (F) acts on an object of mass (m) at rest to move it at a uniform acceleration (a) to reach velocity (v_f) after moving a displacement (d), thus From the third equation of motion: $v_f^2 = v_i^2 + 2ad$

Vi = 0 so $v_f^2 = 2\,a\,d$ $d = \frac{v_f^2}{2a}$ multiplying both sides to F

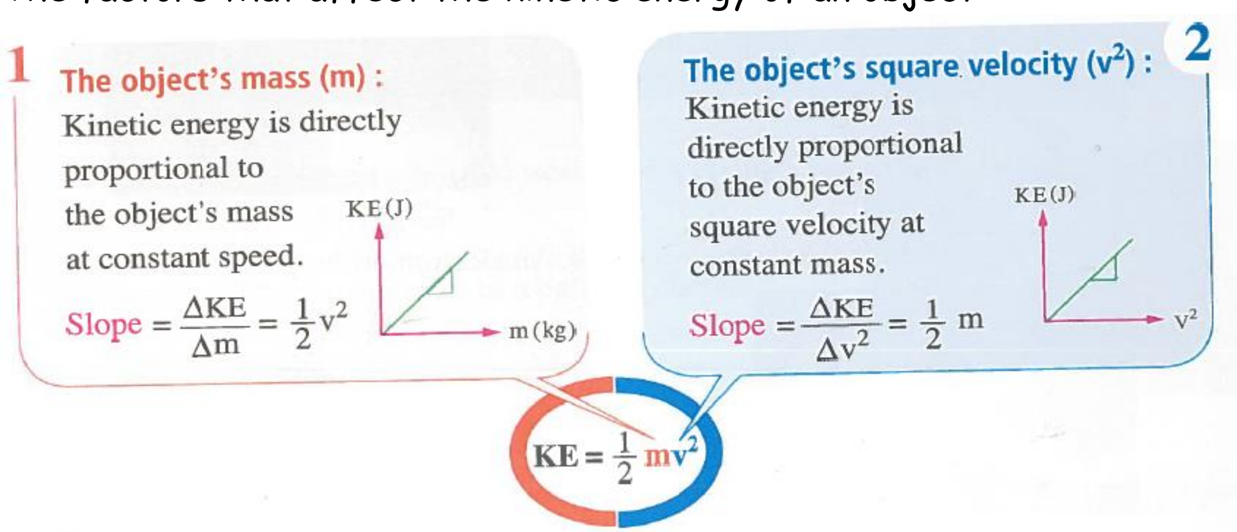
$Fd = \frac{1}{2} * \frac{F}{a} * v_f^2$ but $\frac{F}{a} = m$

So $\boxed{F.d = \frac{1}{2} * m * v_f^2}$

- Fd = work done to move the object till it acquire velocity v_f
- $\frac{1}{2} * m * v_f^2$ = kinetic energy (K.E) that is the form of energy into which the work is converted

$$\boxed{\text{kinetic energy (K.E)} = \frac{1}{2} * m * v_f^2}$$

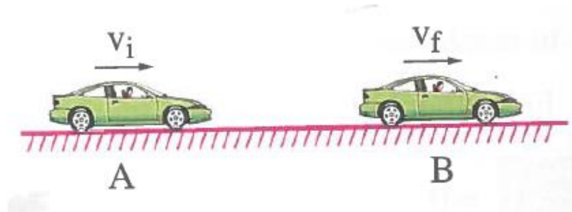
The factors that affect the kinetic energy of an object:



Notes:

1) Kinetic energy is a scalar quantity because it is the product of two scalar quantities which are the object's mass and the square of its speed (or the dot product of the velocity vector times itself).

2) In the opposite figure, the work done by the car to move from position (A) to position (B):



$$W = \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2 = \frac{1}{2} m (v_f^2 - v_i^2) = \Delta(K.E)$$

3) If the work done on a body is:

Positive: the kinetic energy of the body increases by increasing the work done and the velocity of the body increases.

i.e. The resultant force acting on the body is in the same direction of its motion.

Negative: the kinetic energy of the body decreases by decreasing the work done and the velocity of the body decreases.

i.e. The resultant force acting on the body is in the opposite direction of its motion.

Equal to zero: the kinetic energy remains constant which means that the velocity of the body remains constant.

i.e. The resultant force acting on the body vanishes.

Example 1:

Calculate the kinetic energy of a car of mass 2000 kg that is moving with at a velocity of 72 km/h.

Solution: m= 2000kg v=72 km/h

$V= 72 * \frac{5}{18} = 20$ m/s so $K.E = \frac{1}{2} m v^2 = \frac{1}{2} \times 2000 \times (20)^2 = 4 \times 10^5$ joule

Example 2:

A car of mass 1200 kg is moving on a horizontal road, calculate the work done by the car to increase its velocity from 5 m/s to 10 m/s.

Solution: m= 1200 kg v_i= 5 m/s v_f= 10 m/s

$\Delta K.E = \frac{1}{2} m (v_f^2 - v_i^2) = \frac{1}{2} (1200)(100-25) = 4500$ J

Example 3:

A car moves with a velocity of 15 m/s, then the driver applies the brakes, the car stops after covering a distance of 20m. Calculate the distance that would be covered by the car before stopping if the driver applies the brakes by the same force when the car is moving with a velocity of 30 m/s (using the work and energy equations).

Solution: v_i1= 15 m/s d1=20 m d2=?? V_f1=0 v_f2= 30m/s

$-Fd = \frac{1}{2} m (v_f^2 - v_i^2)$ so $-Fd1= \frac{1}{2} m (v_{f1}^2 - v_{i1}^2) = -20*F= \frac{1}{2} m (0 - 15^2)$

For second period $-Fd2= \frac{1}{2} m (v_{f2}^2 - v_{i2}^2)$ so $-Fd2= \frac{1}{2} m (30^2 - 0)$

F & m are const. by dividing 2 equations we found $\frac{d2}{20} = \frac{900}{-225} = 80$ m

Example4:

Two bodies (x) ,(y) have the same mass if their kinetic energies are 100J , 900J respectively and the linear momentum of body (x) is 20 kg.m/s, calculate the linear momentum of body (y).

Solution: mx = my K.Ex = 100J K.Ey = 900J px =20 Kg.m/s

P=mv so v= $\frac{p}{m}$ & K.E= $\frac{1}{2}$ m v_f^2 so K.E= $\frac{1}{2}$ m $(\frac{p}{m})^2$

For body (x) K.E= $\frac{1}{2}$ m $(\frac{p}{m})^2$ so 100 = $\frac{1}{2m}$ $(20)^2$ so m = 2 Kg

For body (y) K.E= $\frac{1}{2}$ m $(\frac{p}{m})^2$ so 900 = $\frac{1}{2m}$ $(p)^2$

But they have the same mass so (mx=my=2)

3600 = $(p)^2$ so p = 60 kg.m/s

Note that momentum (p) is directly proportional to velocity (v)

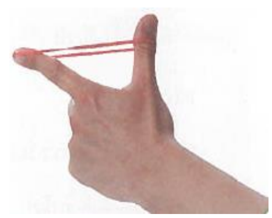
So momentum (p) is directly proportional to $\sqrt{\mathrm{K.E}}$

Second Potential energy:

When work is done on a body to change its position, this work is stored in the body as a form of energy which is called potential energy.

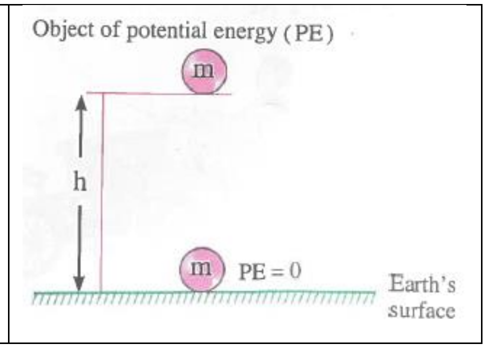
Potential energy :

It is the energy stored in objects because of their new positions or states.

Examples of Potential energy:		
Stored potential energy in a compressed or elongated spring. (elastic potential energy)	When a spring is compressed or elongated, its molecules acquires a new position and they store elastic potential energy. Then, the spring does work to release this energy and restore its original position.	
Stored potential energy in a stretched rubber band. (elastic potential energy)	When a rubber band is stretched, its molecules acquires a new position and they store elastic potential energy. So when removing the acting force on the rubber band, the band shrinks to release this energy and restore its original shape.	
Stored potential energy in an object that is raised off the ground. (gravitational potential energy)	Gravitational potential energy depends on the object's position relative to the Earth's surface (relative to the gravitational field).	
Stored potential energy in the electrons inside a battery. (chemical potential energy)	Electrons flow when the battery is connected to a closed circuit.	

Finding the potential energy of an object:

If an object of mass (m) is lifted up to a height (h), the work done (W) is determined by the relation: $W = F.h$
Where (F) is the force required to lift the object up and equals its weight (w) = m.g



$$W = m.g.h$$

But the work done (W) is stored in the form of Potential energy (P.E)

So $$\boxed{P.E = m.g.h}$$

P.E : is potential energy

m : mass of the object

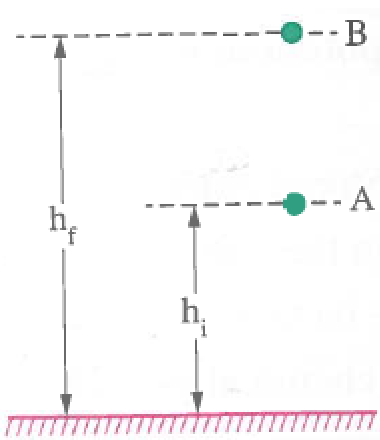
h : height which the body moved to

Note:

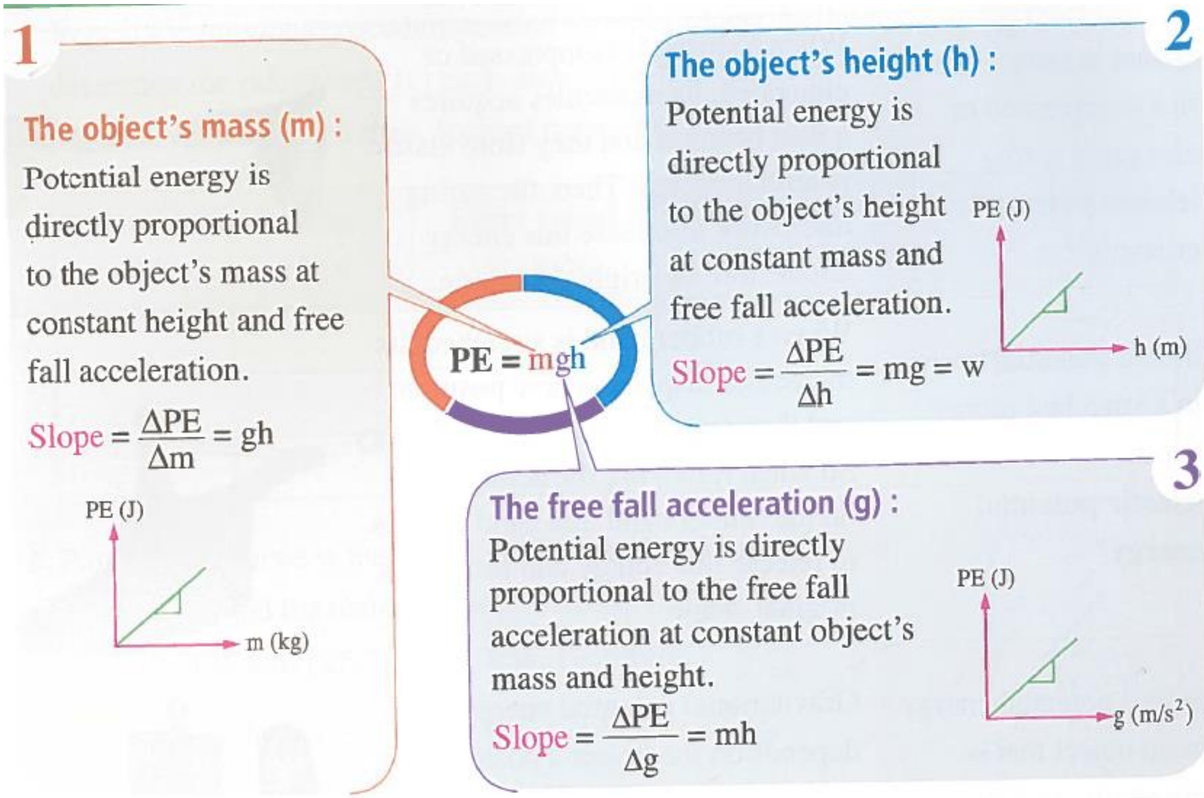
In the opposite figure, the work done to lift a body of mass (m) from the position (A) to the position (B)

$W = m.g.h_f - m.g.h_i = m.g(h_f - h_i) = m.g.\Delta h$

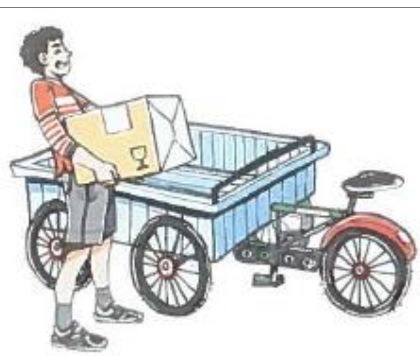
So $$W = \Delta P.E$$



The factors that affect Potential energy of an object:



<u>Life application:</u>

(First case) when lifting a box of weight 450 N vertically upwards to a height of 1 m.	(Second case) when lifting the same box vertically upwards to a height of 1 m by using a ramp (inclined surface) of length 3 m
	

The work done will be W = w.h = 450 $*$ 1 = 450 J

The first object :	The second object :
Needs a force that is equivalent to the box's weight: $F = \frac{W}{d} = \frac{450}{1}$ = 450 N	Needs a force that is less than the box's weight, but needs larger displacement: $F = \frac{W}{d} = \frac{450}{3}$ = 150 N

Example 5:

Two bodies x, y the mass of each is 10 kg, a person lifted the body (x) to a height of 1 m from the Earth's surface and lifted the body (y) to a height of2.5 m from the Earth's surface, calculate:

(a) The change in the potential energy for each of the two bodies.

(b) The work done by the person on each of the two bodies and what do you conclude from that? (knowing that : g = 10 m/s)

Solution: m_x=m_y= 10 kg h_1= 1 m h_2= 2.5 m

a) $\Delta P.E_x = m.g.(h_f - h_i)$ = 10 x 10 x (1-0)= 200 J

$\Delta P.E_y = m.g.(h_f - h_i)$ = 10 x 10 x (2.5-0)= 250 J

b) work done by x = m.g.h = 10 x 10 x 1 = 200 J

work done by y = m.g.h = 10 x 10 x 2.5 = 250 J

We conclude that the work done equals the change in the potential energy. ($W = \Delta PE$)

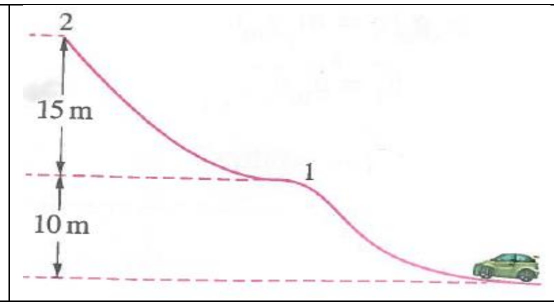
Example 6:

In the opposite figure, a small car of mass 200 kg is moved from the Earth's surface to position (1) then to position (2). Calculate the work done and the change in the potential energy when the car moves from the Earth's surface to:

(a) position (1).
(b) position (2).
(knowing that : g = 10 m/s)

Solution:

m= 200 kg h_1=10m h_2=25m   g=10m/s



Δ P.E1 = m.g.Δh = (200) (10)(10-0) = 20000 J

Δ P.E2 = m.g.Δh = (200) (10)(25-0) = 50000 J

Comparison between Kinetic energy & potential energy		
Comparison points	Kinetic energy	Potential energy
Definition	The energy possessed by the object due to its motion.	The energy stored in the object due to its position or state.
Mathematical expression:	K.E = $\frac{1}{2}$ mv^2	PE = m.g.h
Affecting factors	Object's mass (m) (2) Object's velocity (v).	(1) Object's mass (m). (2) Height above the Earth's surface (3) Free fall acceleration (g).
Unit & dimensions:	Joule (J) or N.m ML^2T^{-2}	Joule (J) or N.m or Kg.m^2.s^{-2} ML^2T^{-2}

Note:

The sum of kinetic energy and potential energy is called mechanical energy.

i.e. Mechanical energy = Kinetic energy + Potential energy

$$ME = KE + PE$$

<u>Physics in environment:</u>

Most of the energy used by man comes from non-renewable resources such as:

- Coal & Petroleum.

• Non-renewable resources of energy are considered as unclean resources since they produce a lot of harmful products to the environment and man health.

• Because of this, there is a global trend, especially in the most industrialized countries, to use the renewable resources such as wind power and waterfalls as an energy resource to generate electricity and preserve the environment, as well.

Exercise 7

Choose the correct answer:

1) An object of mass 2 kg is moving with uniform velocity and its kinetic energy is 25 J, then……………………(Choose two answers)

a) Its velocity equals 100 m/s b) its velocity equals 12.5 m/s

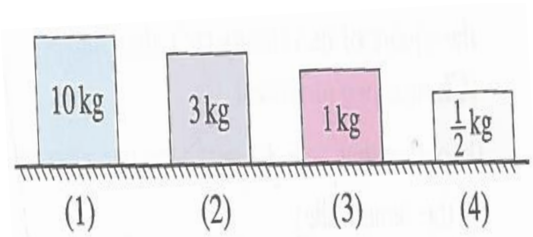
c) Its velocity equals 5 m/s d) the work done on the object equals 25 J

f) The work done on the object equals zero

2) If the four objects have the same speed, then the highest in kinetic energy is.....

a) 1 b) 2

c) 3 d) 4

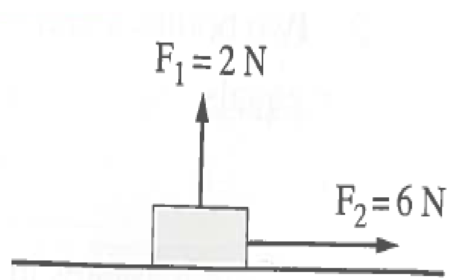


(ii) If the four objects have the same kinetic energy, then the highest in speed is …………………………

a) 1 b) 2 c) 3 d) 4

3) The opposite figure represents two forces F1,F2, that act on a static object to move it horizontally a distance of 4 m, so the change in the kinetic energy of the object is ……………

a) 8J b) 10J c) 24J d) 21



4) The kinetic energy of an object is 4 J. What is its kinetic energy if its speed is doubled? ………………………

a) 0.8J b) 4J c) 16J d) 8J

5) One joule is ……………………. (Choose two answers)

a) The kinetic energy of a ball of mass 2 kg that moves with a velocity of 1 m/s

b) The measuring unit of each of weight and force

c) The work done by a horizontal force of 1 N to displace a body a horizontal displacement of 1 m

d) Equivalent to Newton/meter

(e) The measuring unit of each of work and momentum

6) If the velocity of an object is doubled and its mass decreases to its quarter, so its kinetic energy ……………………

a) Decreases to its half b) remains constant

c) Decreases to its quarter d) is doubled

7) when the speed of a car is doubled, its kinetic energy …………………

a) is halved b) is doubled

c) increases 4 times d) remains constant

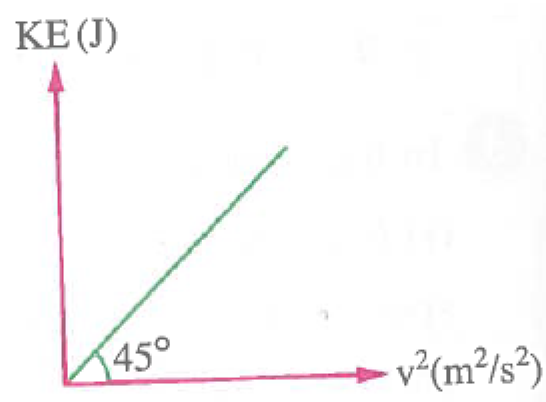
8) Two objects, the mass of the first is double that of the second and the velocity of the first is half that of the second. So, the kinetic energy of the first is…………………… that of the second.

a) half b) double c) quarter d) 4 times

9) Two bodies a,b the mass of a is 4 times that of b,if the two bodies have the same kinetic energy, then the ratio between their linear momentums……………

a) $\frac{1}{2}$ b) $\frac{2}{1}$ c) $\frac{4}{1}$ d) $\frac{1}{4}$

10) The opposite graph represents the relation between the kinetic energy (KE) of a body of mass (m) and the square of its velocity (v), then the.................
(Choose two answers)
(knowing that : $g = 10\ m/s^2$, the two axes are drawn by the same scale)



a) Mass of the body equals 0 .5 kg

b) mass of the body equals 2 kg

c) Weight of the body equals 20 N

d) mass of the body equals 1 kg

e) Weight of the body equals 0 .05 N

11) The stored energy in a compressed spring is ……………………………

a) Kinetic energy

b) potential energy

c) nuclear energy

d) repulsion energy

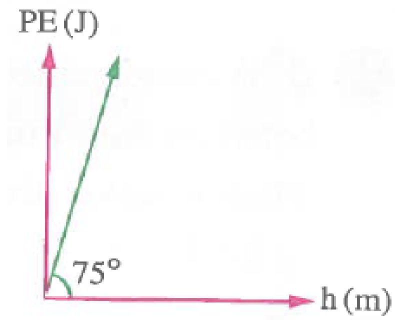
12) a book of mass 2 kg that is placed on a table at hight 0.5 m, so the potential energy of the book equals ……………
(knowing that:$g = 9.8\ m/s$)

a) 98 J b) 10 J c)2.5 J d) 9.8 J

13) A ball of mass (m) is moving horizontally with velocity (v) where it collides with a wall and rebounds by half its velocity, so the energy lost due to the collision equals……………………..

a) $\frac{1}{8}$ mv^2 b) $\frac{3}{8}$ mv^2 c) $\frac{1}{2}$ mv^2 d) $\frac{1}{4}$ mv^2

14)The opposite graph represents the relation between the potential energy of a body (PE) and its height (h) from the Earth's surface, then the ………………… (Choose two answers)



(knowing that: $g = 9.8\ m/s^2$, the two axes are drawn by the same scale)

a) slope of the line represents the mass of the body

b) slope of the line represents the weight of the body

c) c) slope of the line represents the velocity of the body

d) mass of the body equals 0.4 kg

e) e) mass of the body equals 3.7 kg

15) Two bodies x and y have the same mass, if (KE)x = 4 (KE)y then the momentum of x equals ......

a) Py b) 2Py c) 4Py d) 8Py

16) A particle rotates in a uniform circular path of radius 20 cm where a centripetal force of 10 N acts on it, so the particle's kinetic energy is ………………

a) 0.1J b) 80.21 c) 2J d) 1J

17) A bullet penetrates a wooden block and loses half its velocity. What is the ratio between the initial kinetic energy of the bullet and the kinetic energy of the bullet when it leaves the block? …………………………

a) 1:2 b) 1:4 c) 2:1 d) 4:1

18) 4 kg cart has a linear momentum with a magnitude of 20 kg.m/s. What is the cart's kinetic energy ………………

a) 20 b) 30 c) 50J d) 100J

Second Problems:

1) Find the kinetic energy of a car of mass 2000 kg that is moving at a speed of 60 km/h.

………
………(2.78x10^5 J)

2) A runner of mass 72 kg has the same kinetic energy of a car of mass 1200 kg that moves at a velocity of 2 km/h. Find the velocity of the runner.

………
………(2.27 m/s)

3) An object of mass 12 kg starts its motion from rest with uniform acceleration of 10 m/s. Calculate its velocity and its kinetic energy after covering a distance of 80 m.

………
………
…………………………………………………………………………………………………… (40 m/s, 9600 J)

4) A force of 36 N is acting on an object of mass 25 kg in a direction that makes an angle of 60° with the horizontal. Calculate the velocity of the object after covering a horizontal distance of 100 m if it started its motion from rest.

………
………(12 mls)

5) A machine gun fires 600 bullets per minute. If the mass of one bullet is 49 g and its velocity is 200 m/s, find the kinetic energy generated per second.

……
……(9800 J)

6) The kinetic energy of an object is 36 J and its momentum is 18 kg.m/s,calculate :

(a) The velocity of the object.
(b) The mass of the object.

……
……
……………………………………………………………………………………………………(4 m/s, 4.5 kg)

7) What is the change in kinetic energy when a 50 g ball hits the pavement with a velocity of 6 m/s and rebounds with a velocity of 10 m/s?

……
…….(1.6 J)

8) An athlete of weight 700 N has climbed a mountain to a height of 200 m from the ground. Find the work done by him.

……
……(14×10^4)

9) The mass of the load is 100 kg, find the work done by the weight lifter to lift a load distance of 2 m. (where: g = 10 m/s)

……
……(2000 J)

Unit Four
Chapter 2
(Law of conservation of Energy

We have studied in the previous chapter that energy is the capacity to do work and there are different forms of energy that can be converted into one another, such as:

Potential energy	Converts to Kinetic energy in a waterfall.	
Chemical potential Energy stored in coal and gasoline and other types of fuel.	Converts to thermal energy then mechanical work that is used by means of transportation such as cars and trains.	
Electrical energy in the electric bulb.	Converts to thermal and light energies.	
Chemical potential energy stored in a battery.	Converts to electrical energy when a battery is connected in a closed circuit.	
Chemical potential energy stored in wood.	Converts to Thermal and light energies at burning.	

On converting energy from one form into another, the amount of energy remains constant and this is known as the law of conservation of energy.

Law of conservation of energy:

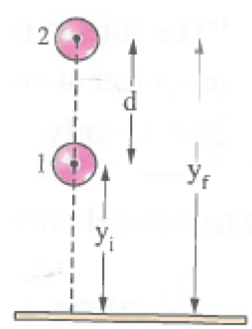
"Energy is neither created nor destroyed, but it can be converted from one form into another."

Through the following, we will study one of the forms of the law of conservation of energy which is the law of conservation of mechanical energy.

Law of conservation of mechanical energy

Assume that an object of mass (m) is projected vertically upwards from point (1) at initial velocity (v_i) to reach point (2) at final velocity (v_f), the work done by the gravitational force on the object while rising leads to:

1. An increase in the potential energy of the object by increasing the height.
2. A decrease in the kinetic energy of the object due to a decrease in its velocity.



We can say that $\boxed{PE_f + KE_f = PE_i + KE_i}$

This means that:

The sum of potential energy and kinetic energy at point (1) equals the sum of potential energy and kinetic energy at point (2).

Conclusion:

1. The sum of potential energy and kinetic energy of an object at any point on its path under the effect of gravity only is constant.

2. The increase in the kinetic energy of a falling object will be on the expense of its potential energy i.e. Potential energy decreases and vice versa.

From the previous, we can define the mechanical energy and the law of conservation of mechanical energy as follows:

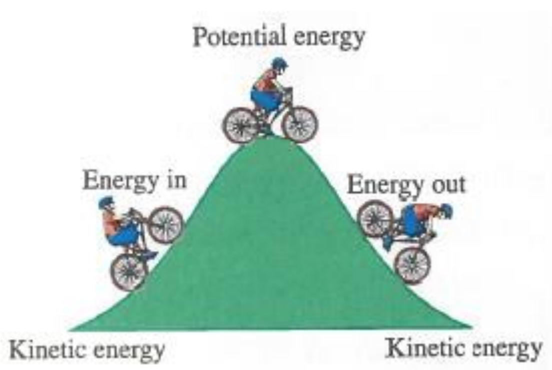
1- The mechanical energy:

It is the sum of potential energy and kinetic energy of an object.

Mechanical energy (ME) = PE + KE

2- Law of conservation of mechanical energy:

"The sum of potential energy and kinetic energy of an object at any point on its path under the effect of gravity only is constant".



Notes

When an object moves vertically under the effect of the acceleration due to gravity, then:

- At the maximum height:

vf=0 ∴ KE=0 ∴ Mechanical energy (ME)= PE

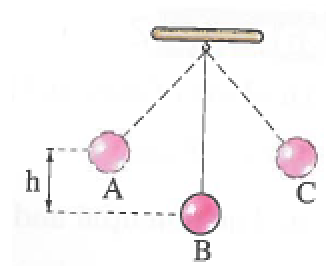
- At the mid-distance between the ground and the maximum height: KE = PE ∴ ME = 2 KE = 2 PE

- At the moment , the object touches the ground :

∵ h = 0 ∴ PE = 0 ∴ ME = KE So : PE at maximum height = KE at the ground

2- In case of a simple pendulum as in the figure :

- The position (B) is called the equilibrium position at which the velocity of the pendulum ball is maximum.



At the two positions (C) and (A), the ball makes its maximum displacement away from position (B) and the velocity of the ball at them equals zero and also its kinetic energy so at these positions the mechanical energy of the ball equals the potential energy.

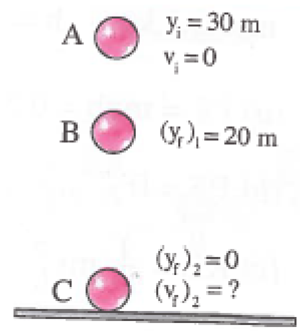
- The height (h) in the relation (PE = mgh) represents the vertical distance between the position of the pendulum ball at any point and the equilibrium position.

Example 1:

In the opposite figure, a static object at a height of 30 m above the ground (at point A) has a potential energy of 1470 J. If this object falls neglecting the air resistance and considering $g = 9.8\ m/s^2$. Find:

(a) The kinetic energy and potential energy of the object at a height of 20 m above the ground.

(b) The object's velocity at the instant of hitting the ground.



Solution: $h_i = 30$ m   PEi= 1470 J   vi = zero $g= 9.8\ m/s^2$

a) At point (A) PEi = mgh so m x (9.8) x (30) = 1470 $\therefore$ m = 5 kg

At point (B) height = 20 so PE= mgh = (5)(9.8)(20) = 980 J

Also   PEi +KEi = PEf +KEf

1470 + 0 = 980 + ???

KEf= 1470 – 980 = 490 J

b) PEi + KEi = PEf + KEf

$1470 + 0 = 0 + \frac{1}{2} mv^2 \quad \therefore\ v^2 = \frac{2}{5} \times (1470) \quad \therefore\ v = 24.25\ m/s$

Example 2:

An object of mass 0.5 kg falls freely from a point at a height of 100 m from the Earth's surface. Find:

(a) The potential and kinetic energies at the top.

(b) The potential and kinetic energies at the ground.

(c) The velocity of the object on touching the ground.(where: g= 10 m/s)

Solution: m=0.5 kg h=100 m vi=0

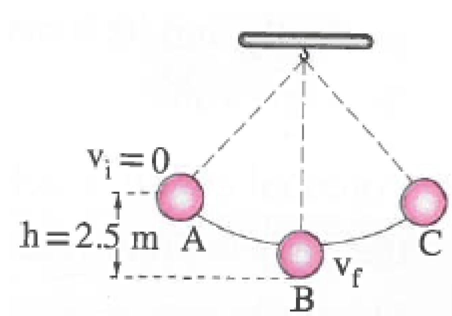
a) KE at the top = zero & PE = mgh = 0.5 x 10 x 100 = 500 J

b) PE at the ground = zero & KEi +PEi = KEf + PEf $\therefore$ KE = 500J

c) KE = $\frac{1}{2}$ mv^2 $\therefore$ 500 = $\frac{1}{2}$ x 0.5 x v2 $\therefore$ v^2 = 4 x 500 = 2000, v=44.72 m/s

Example 3:

The diagram illustrates a ball hung by a thread that swings in a certain plane. If the ball's mass is 4 kg and g = 9.8 m/s, find the maximum velocity that can be reached by the ball during oscillation, neglecting the air resistance.



Solution:

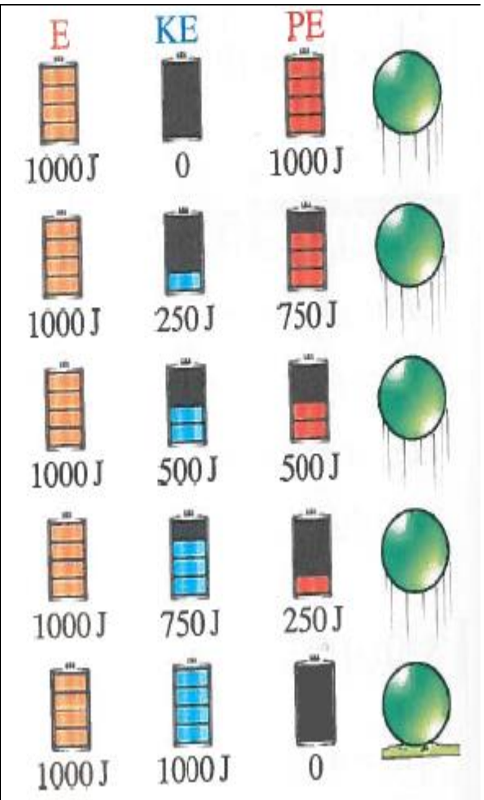
The greatest velocity of the ball during oscillation is at the point (B).

By applying the law of conservation of mechanical energy at the points A and B :(PE), + (KE),= (PE), + (KE), mgh + 0=0+ $\frac{1}{2}$ mv^2

gh = 0.5 v^2 $\therefore$ v^2 = 2 x (9.8)x(2.5) v= 7 m/s

Law of conservation of energy every day:

Projecting an object upwards:

-When a ball is projected vertically upwards from the ground its potential energy equals zero at the ground, while its kinetic energy is maximum. -As the ball rises, its potential energy increases gradually and its kinetic energy decreases by the same value. - Potential energy reaches its maximum value at the highest point reached by the ball where its kinetic energy = zero. - When the ball starts to return back to the ground, its kinetic energy increases gradually, while its potential energy decreases. - When the ball reaches the ground, the potential energy becomes zero at the ground while kinetic energy becomes maximum.	
The roller coaster : Where the cart acquires the maximum potential energy at the top which is then converted into kinetic energy on falling	
In pole vault : Where the potential energy is stored in the pole during the jump and then converted into kinetic energy.	

When shooting arrows : Where potential energy is stored in the stretched string and then converted into kinetic energy when the string is released.	
The stagnant water behind the dam : Where the water stores potential energy which is converted into kinetic energy when the water start falls through the dam.	

Conclusion:

1. By increasing height, the potential energy increases.

2. Potential energy. $_{\text{At maximum height}}$ = Kinetic energy $_{\text{at the ground}}$ = Mechanical energy

i.e. Mechanical energy= Potential energy+ Kinetic energy= constant

Exercise 8

Choose the correct answer:

1) When an object is projected vertically upwards, which of the following physical quantities will equal zero at the maximum height ……

a) The gravitational force b) The acceleration

c) The potential energy d) The velocity

2) When an object is thrown upwards

a) KE increases and PE decreases b) both PE and KE increase

C) KE decreases and PE increases d) both PE and KE decrease

3) When an object falls freely, then its .... during falling. (Choose two answers)

a) mechanical energy increases

b) mechanical energy decreases

c) mechanical energy remains constant

d) potential energy decreases and its kinetic energy increases

e) potential energy increases and its kinetic energy decreases

4) When an object is thrown vertically upwards, its mechanical energy will .

a) increase b) decrease

c) be constant at any point d) no correct answer

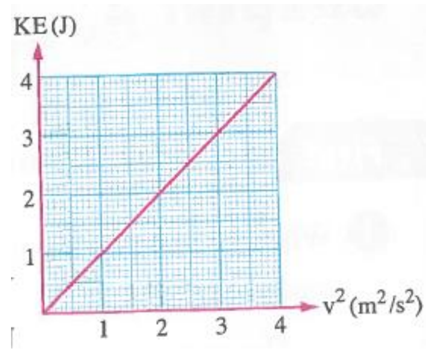
5) The ratio between the mechanical energy of an object that is projected vertically upwards and its potential energy at maximum height is ………………………

a) 1:1 b) 2:1 c) 1:2 d) 1:3 e) 3:1 f) 0 g) 1:4

6) A object of mass 12 kg is falling freely from a certain height, if its mechanical energy at the mid-distance between its initial position and the ground is 150 J, then its speed at the instant of touching the ground = ... m/s

a) 50 b) 625 c) 5 d) 20

7) A body falls from a height of 18 m from the Earth's surface and the opposite graph represents the relation between the kinetic energy of the body (KE) and the square of its velocity (v) during falling, so the ………………… (Choose two answers)



a) mass of the body = 1 kg and the mechanical energy = 180J

b) mass of the body = 2 kg and the mechanical energy = 360 J

c) potential energy of the body at height of 4 m equals 360 J

d) kinetic energy of the body at height of 10 m equals 160 J

e) kinetic energy of the body at height of 12 m equals 180J

8) Object of mass 5 kg falls from a height of 10 m from the Earth's surface, then the……………… (g = 10 m/s) (Choose two answers)

a) Kinetic energy of the object at height of 10 m = the mechanical energy of the object

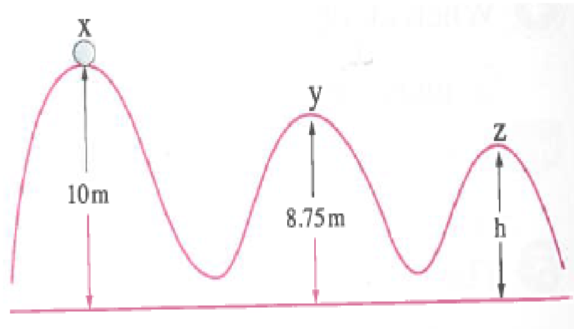
b) Potential energy of the object at the Earth's surface = the mechanical energy of the object.

c) Kinetic energy of the object at height 5 m = Half the value of the mechanical energy of the object.

d) Kinetic energy of the object at height 3 m = the potential energy of the object at height 7 m.

e) Kinetic energy of the object at height 4 m = Double the potential energy of the object at height 6 m.

9) In the opposite figure: A static body of mass 1 kg slides on a smooth curved path starting from point x, then :
(i) The velocity of the body at point y equals ……………………………

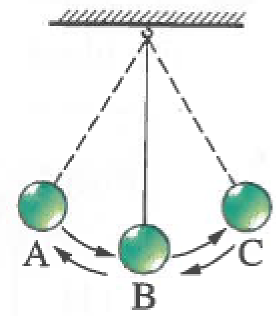


a) 3m/s b) 5m/s c) 6 m/s d) 6.5 m/s

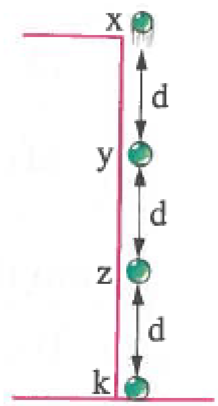
(ii) If the body reaches point z with velocity 7 m/s, then the height of point z from the ground equals......• (where:g = 10 m/s)

a) 8.45m b) 7.55m c) 7.25m d) 6.85 m

10) The opposite figure shows a simple pendulum that swings, then ……………
a) KE at C is maximum
b) The mechanical energy at A > the mechanical energy at B
c) PE at A is maximum
d) PE at C > PE at A

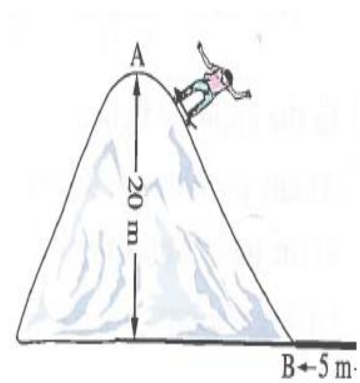


11)The opposite figure shows a body that falls from the top of a building of height 3 d, then …………… (Choose two answers)



a) PE at x = KE at y
b) PE at y > KE at k
c) KE at z = PE at y
d) PE at x > KE at k
e) KE at z > PE at k

12) Te opposite figure shows the path of a skater of mass 80 kg that skates from rest from the top of a hill at a height 20 m from the ground. If the path from point A to point B is smooth and the path from point B to point C is rough , then the average friction force required to stop the skater at point C is ……………………



(where :g = 10 m/s)

a) -1600N
b)-2400N
c) -3200 N
d) -4000 N

Second Problems:

1) An object is thrown upwards with initial velocity 10 m/s. If its potential energy at maximum height is 1000 J, find its mass.

……

………(20 kg)

2) A ball of mass 200 g falls from a height of 100 m. Calculate the mechanical energy of the ball when it reaches half this height. (where: g = 10 m/s)

……

………(200 J)

3) A ball of mass 0.5 kg is projected vertically upwards. If its velocity at 4 m high is 3 m/s, find the work done to project the ball, given that acceleration due to gravity= 10 m/s

……
……
……………………………………………………………………………………………………(22.25 J)

4) Calculate the work done by a worker to carry a sack of cement of mass 50 kg to a height of 20 m. If the sack falls from him to the ground, find its velocity when it reaches the ground. (Where: g =9.8 m/s)

……
……
…………………………………………………………………………………………….(9800J,19.8 mls)

5) As object of mass 1 kg is projected vertically upwards by a velocity of 24.5 m/s, calculate its potential energy when its speed becomes 4.9 m/s. (where : g = 10 mls2)

……
……
……………………………………………………………………………………………………… (288 J)

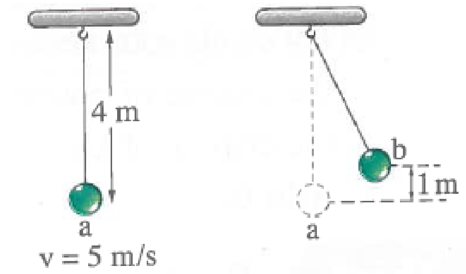
6) An object of mass 0.2 kg is projected vertically upwards by a velocity of 20 m/s, neglecting the air resistance, calculate:

(a) The maximum height reached by the object.

(b) The speed of the object at a height of 10 m from the ground. (where: g = 10 m/s)

……
……
……………………………………………………………………………………………(20m,14.14 mls)

7) By using two opposite figures, calculate:
(a) The velocity of the body at point (b).
(b) The maximum height reached by the body.(where :g =9.8 m/s)

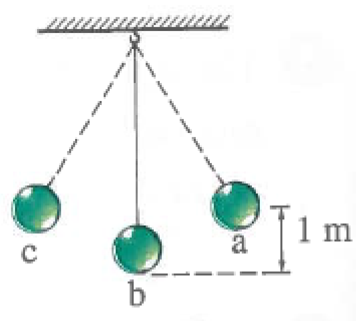


……

……

………………………………………………………………………………………(2.32mls, 1.28 m)

8) In the opposite figure a simple pendulum of mass 15 g starts its motion at point band its speed reaches zero at points a, c. Calculate the maximum potential energy and the maximum kinetic energy if the acceleration due to gravity is 10 m/s.



……

……

…………………………………………………………………………………………(0.15 J, 0.15 J)

9) Two objects falls at the same instant where the mass of the first object is 3 times that of the second object and the first object falls from a height that is the height from which the second object falls. Find the ratio between the kinetic energy of the first object and the kinetic energy of the second object at the instant of reaching ground.

……

……

………(1:1)

9) An object is projected vertically upwards with a velocity of 20 m/s from the top of a building of height 15 m. So, the object's kinetic energy equals its potential energy at a height of .... from the ground. (where:g = 10 m/s)

……
……
……………………………………………………………………………………………………….(17.5m)

10) If a body of mass 19 kg falls freely from a height of 60 m, calculate its kinetic energy at the midpoint of the falling distance. (where :g = 10 m/s)

……
……
………………………………………………………………………………………………………(5700 J)